REPORT OF THE SIXTH COMMONWEALTH MYCOLOGICAL CONFERENCE 1960

THE COMMONWEALTH MYCOLOGICAL INSTITUTE
KEW · SURREY
1961

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Commonwealth Agricultural Bureaux

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OCCASIONAL PUBLICATIONS OF THE COMMONWEALTH MYCOLOGICAL INSTITUTE

Mycological Papers, containing descriptions of new species and varieties and revisions, as well as lists of fungi and plant diseases in overseas countries and miscellaneous information.

Phytopathological Papers: monographic descriptions of crop diseases of economic importance.

A MANUAL OF RICE DISEASES by G. WATTS PADWICK, 198 pp., 48 fig., 1950. 30*s*.

FUNGI AND PLANT DISEASES IN THE SUDAN by S. A. J. TARR, 55 pp., 12 pl., 1951. 12*s*. 6*d*.

TOBACCO DISEASES with special reference to Africa by J. C. F. HOPKINS, 204 pp., 59 pl., 1956. 35*s*.

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1. Calling the Conference

In accordance with a resolution passed by the Imperial Mycological Conference in 1924 similar conferences have been held at intervals of five years, but the sequence was interrupted by the Second World War. The sixth such conference was due in 1959 but was postponed to 1960 to coincide with the Seventh Commonwealth Entomological Conference in order that a joint session might be held and that delegates could have the opportunity of attending both if Governments so desired. Accordingly, invitations were issued by the Executive Council in May 1958 to governments to send delegates to a conference to be held in London from 15 to 22 July 1960.

2. Delegates

The following attended the conference:-

Australia
Dr. C. J. Magee

Canada
Dr. J. B. Lebeau

Ceylon
Mr. O. Peries
Mr. N. Shanmuganathan

Colonial Office
Mr. D. Rhind
Mr. G. M. Roddan

Federation of Malaya
Mr. W. P. Ting

India
Dr. B. L. Chona

Jamaica
Mr. G. Stell

Kenya
Dr. I. A. S. Gibson

New Zealand
Dr. G. H. Cúnningham

Nigeria
Mr. R. E. Wyatt

Nyasaland
Mr. D. C. M. Corbett

Republic of Ireland
Dr. J. B. Loughnane

Sierra Leone
Mr. C. T. Pyne

South Africa
Mr. L. D. Wolfswinkel

Tanganyika
Mr. P. K. S. Clinton

United Kingdom
Mr. F. C. Bawden
Dr. A. E. W. Boyd
Dr. P. H. Gregory
Mr. W. C. Moore
Mr. J. S. Murray
Dr. M. Noble
Mr. L. Ogilvie
Mr. T. R. Peace
Dr. A. F. Posnette
Mr. G. G. Samuel

In addition the following research stations were represented:-

Empire Cotton Growing Corporation, Uganda
Mr. D. A. Perry

Imperial College of Tropical Agriculture, Trinidad
Mr. E. F. Iton

Rubber Research Institute, Malaya
Mr. R. A. Fox

West African Cocoa Research Institute, Ghana
Mr. P. D. Turner
Mr. A. L. Wharton

West African Institute for Oil Palm Research, Nigeria
Mr. J. S. Robertson

and Dr. Lee Ling attended as Observer for the Food and Agriculture Organization of the United Nations.

VISITORS

Invitations to attend the Conference and take part in the discussions were issued to the staffs of Agricultural and Horticultural Research Stations, University Departments, and individual mycologists in the United Kingdom and to the representatives of various firms interested in the manufacture of fungicides and machinery. Many visitors were able to attend and they made valuable contributions to the discussions.

3. Place of Meetings

By the courtesy of the Dean, meetings of the Conference and Committees were held at the London School of Hygiene and Tropical Medicine, Malet Street, London, W. C. 1, where refectory arrangements were also put at the disposal of delegates.

On Thursday, 14 July, a joint session was held with the Seventh Commonwealth Entomological Conference in the Memorial Hall of the Royal Geographical Society, Exhibition Road, London, S. W. 7, a full account of which appears in the report of that conference, pp. 157 to 195 [London. Commonwealth Institute of Entomology, 56 Queen's Gate, S. W. 7, 1960, price 50s.]

4. Official Reception

On July 14, Her Majesty's Government in the United Kingdom received delegates to the Commonwealth Entomological and Mycological Conferences at a reception held at Lancaster House, St. James's. The Minister of Science and Lord President of Council, the Right Honourable Lord Hailsham, Q. C., gave an address of welcome to the delegates which was responded to by Mr. F. Wilson (Australia).

5. Programme

Thursday 14 July

JOINT MEETING WITH THE SEVENTH COMMONWEALTH ENTOMOLOGICAL CONFERENCE

10 a.m. Developments in the study of plant viruses and their vectors and their bearing on control measures
Chairman: Mr. F. C. Bawden

2.15 p.m. The link between research work and its application in the field of plant protection
Chairman: Prof. V. B. Wigglesworth

6.30 p.m. Official reception for Delegates to the Entomological and Mycological Conferences at Lancaster House, St. James's, S.W.1.

SIXTH COMMONWEALTH MYCOLOGICAL CONFERENCE

FRIDAY 15 JULY TO FRIDAY 22 JULY

Friday 15 July

10 a.m. Official Opening of the Conference by the Chairman of the Executive Council of the Commonwealth Agricultural Bureaux, Mr. A. Perera

10.30 a.m. Plenary session. Report by the Director on the work and organization of the Commonwealth Mycological Institute, 1954-1960.

11.15 a.m. Information service for plant pathology.
Chairman: Mr. G. G. Samuel

2.30 p.m. Taxonomy in relation to plant pathology
Chairman: Dr. G. H. Cunningham

5.30 p.m. Reception of Overseas Delegates by Institute of Biology at 41 Queen's Gate, South Kensington, S.W.7.

Saturday 15 July

Visit by Delegates and Observers to the Commonwealth Mycological Institute, Kew.

10 a.m. Meetings of delegates and committees

2.30 p.m. Inspection by Conference Delegates of the Commonwealth Mycological Institute

Monday 18 July

10 a.m. Root diseases
Chairman: Dr. J. B. Lebeau

2.15 p.m. Seed pathology
Chairman: Dr. F. Joan Moore

Tuesday 19 July

10 a.m. Forecasting and Assessment
Chairman: Dr. P. H. Gregory

2.30 p.m. Fungicides
Chairman: Dr. C. J. Magee

Wednesay 20 July

Joint visit with the 34th Annual Plant Pathology Field Meeting of the British Mycological Society to the John Innes Institute, Bayfordbury, Herts. Delegates were welcomed by the Director, Dr. K. S. Dodds, who briefly outlined the history and work of the Institute, and were entertained to luncheon. Afterwards the laboratories and glasshouses were visited where demonstrations had been arranged, and opportunity was afforded delegates to discuss the work of the Institute with members of the staff.

Thursday 21 July

10 a.m. Virus diseases and cereal rusts
Chairman: Dr. B. L. Chona

2.30 p.m. Diseases of cacao and black pepper
Chairman: Prof. N. F. Robertson

Friday 22 July

10 a.m. Meetings of Committees

2.30 p.m. Final plenary session

EXCURSIONS

During the week after the Conference the following excursions took place:

Monday 25 July, National Vegetable Research Station, Wellesbourne, Warwick

Tuesday 26 July, Glasshouse Crops Research Institute, Littlehampton, Sussex

Wednesday 27 July, Plant Pathology Laboratory, Harpenden, and Rothamsted Experimental Station

Thursday 28 July, Fernhurst, Sussex (a.m.) and Jealott's Hill Research Station Bracknell, Berks. (p.m.) at the invitation of Messrs. Plant Protection Ltd. and Imperial Chemical Industries Ltd. respectively.

6. Opening of the Conference

The Conference was opened on July 15 by Mr. A. Perera, Chairman of the Executive Council of the Commonwealth Agricultural Bureaux. He said:

It gives me the greatest pleasure, as Chairman of the Executive Council of the Commonwealth Agricultural Bureaux, to be associated with you this morning at the opening of the sixth Commonwealth Mycological Conference. I also take this opportunity to welcome the delegates and observers to this important Conference.

Several of you have attended previous Conferences, and, it may be, that some have not done so. Perhaps it is in the interests of those who have come here for the first time if I, in the course of my address, were to give them some idea of the background of these Conferences.

These Conferences are normally held once in five or six years. They have a dual purpose. The first is to give the mycologists of the Commonwealth an opportunity to meet and discuss their scientific problems; and the second is to give them an opportunity as representatives of the Commonwealth countries that jointly finance the Mycological Institute to consider the work of the Institute, see how far it meets the needs of their countries and to suggest on technical grounds

the changes that may be considered necessary.

It is to achieve the first purpose that a full programme of scientific discussion has been arranged which should provide a useful opportunity for presenting recent advances in knowledge on many different subjects and for the exchange of views between people interested in different aspects of them. It is hoped that the knowledge gained will lead to further advances both in understanding the problems and the application of methods of solving them.

The second purpose, namely, the work of the Institute, is the one with which the Executive Council of the Commonwealth Agricultural Bureaux is more closely concerned.

The C.A.B. organization, as you may no doubt be aware, has three Institutes and ten Bureaux. It has a common fund to which the independent Commonwealth countries contribute agreed proportions. The administration and financial control of the whole organization are vested in an Executive Council composed of a representative from each of the contributing countries. It is from this common fund that the Mycological Institute is financed.

The work of the C.A.B. organization is also reviewed every five years. The next C.A.B. Review Conference is due next month. At these Review Conferences, where the contributing Commonwealth countries are represented, the work of the whole C.A.B. organization is carefully gone into and suggestions are put forward, wherever changes are considered necessary, for acceptance by Partner Governments. These include activities of each of the Institutes and Bureaux, the cadre, accommodation, finance, and so on, for a period of five years and until the next C.A.B. Review Conference.

Although the task of determining the necessary finance and reviewing the work of this Institute is undertaken by the C.A.B. Review Conference, it is important that the views of this Conference, (representing as it does, the scientists throughout the Commonwealth who actually use or who are dependent to a greater or less extent upon the services offered by this Institute) should be made known as regards technical matters affecting them.

The work of this Institute is given in detail in the Memorandum which has been prepared by the Director [see Conference Proceedings] and you will have ample opportunity to study it and express your views. These will be received by the Executive Council with the most serious consideration and they will also be of great assistance to the delegates to the forthcoming Review Conference.

I do not wish to take your valuable time in referring to staff changes that have occurred in this Institute since the previous Conference, but I should say that this Institute has had the good fortune to have had as its past Directors eminent men with a high sense of duty. We are also very fortunate in having such a distinguished and capable person as our present Director. I do hope that this Institute will have the benefit of his valuable services for many years to come. A word of thanks is also due to the staff who have carried out their duties with efficiency and loyalty.

In conclusion, I trust that this Conference will achieve the purpose for which it has been convened, and with my best wishes for its success, I declare the Conference now open.

At the conclusion of his opening address the Chairman called upon Mr. E. W. Mason to present him with a specially bound copy of the HERB. I. M. I. HANDBOOK as a token of esteem for the invaluable work he had performed for mycology during his forty years service at the Commonwealth Mycological Institute. Mr. Mason expressed his thanks and appreciation.

7. The Work and Organization of the Commonwealth Mycological Institute

At the conclusion of the Official Opening the Director reviewed the work of the Commonwealth Mycological Institute since the last Conference. His report is published below in the proceedings of the Conference.

8. Appointment of Committees

(a) The Conference as a whole decided to go into Committee to consider the work and needs of the Institute.

(b) A Resolutions Committee was appointed as follows

Mr. G. G. Samuel
Dr. P. H. Gregory
Dr. C. J. Magee

9. Proceedings of Conference

Papers presented to the Conference and the resulting discussions are published below in the Proceedings.

10. Report of the Technical Committee

ON THE WORK AND NEEDS OF THE COMMONWEALTH MYCOLOGICAL INSTITUTE

The following report was unanimously adopted at the Plenary Session on Friday, July 22.

1. We were appointed on 16th July to consider the work and needs of the Institute. We inspected the Institute and discussed its work with members of the staff and with the Director, Dr. Hopkins, who has aided us greatly in our deliberations.

2. We noted with satisfaction the increasing demands made on the services of the Institute by Commonwealth plant pathologists and mycologists as a testimony to the value of its work. Since the last Conference there has been a notable expansion in accommodation, staffing, and equipment.

3. Change in Directorship. In 1956, Dr. S. P. Wiltshire retired from the Directorship after many years of devoted service to the Institute. He was succeeded by Dr. J. C. F. Hopkins, under whose leadership the Institute has continued to progress. Dr. Hopkins has already made a number of journeys within the Commonwealth, visiting Canada, Malta, and various territories in Africa at the request of their respective governments.

4. New Building. The new Building, planned while Dr. Wiltshire was Director, was officially opened in July, 1955. The extra accommodation provided by this building was very badly needed and working conditions for the staff have been greatly improved by it. However, the space available is rapidly filling up and it may be necessary to consider some addition to the present buildings in the quinquennium beginning in 1967.

5. The Work of the Institute. We wish to express our great appreciation of the services rendered by the Commonwealth Mycological Institute to all branches of Plant Pathology in the Commonwealth. A valuable staff of specialists has been built up, supported by an efficient team of abstractors, technical and clerical workers, all co-operating loyally in the various activities of the Institute. The laboratories, library, and herbarium are efficiently maintained and effectively used and increasing numbers of visiting workers are making use of the Institute for longer or shorter periods of study. We believe it would be to the advantage of mycology if some of these workers could remain for periods of six months or more.

6. Exchanges and visits. In order to further the identification service there is vital need for a broad investigation into the relationship of taxonomically difficult groups of fungi and bacteria, and economically important pathogens. We consider that more visits by scientific staff to Commonwealth and foreign herbaria would benefit the identification service of the Institute, and that in addition occasional exchanges of taxonomists should be arranged between the Institute and overseas laboratories.

7. Future Conferences. Because the science of Plant Pathology has widened during the last 40 years we suggest that the next Conference might with advantage be named

"The 7th Commonwealth Conference on Plant Pathology". We further suggest that at future Conferences more time should be allotted for specialised discussion of selected subjects.

8. Staff. We consider that the professional staff (in A/B grades), which has been reinforced since the 1954 Conference, should be adequate for the needs of the next quinquennium unless unforeseen demands are made on the Institute. We consider, however, that provision should be made for two appointments in a technological (C) grade, to take some of the load of routine identification off the A/B grades. The number of abstractors appears sufficient for the present, but there is need for another technician to assist with photographic and other work, and for two extra clerks to deal with filing and card-indexing.

9. Bacteriology. The recent appointment of a bacteriologist for work on plant pathogenic bacteria is a valuable step in the study of these organisms, some of which are particularly important in tropical agriculture. We consider that for the efficient carrying out of this work a glasshouse should be provided as soon as possible to enable essential pathogenicity tests to be made on living plants, provided suitable arrangements can be made with the Ministry of Agriculture, Fisheries, and Food, regarding the importation and keeping of the material. Consideration will have to be given to ways of avoiding duplication with the National Collection of Plant Pathogenic Bacteria housed at the Ministry of Agriculture's Plant Pathology Laboratory at Harpenden.

10. Photographic and optical equipment. We were impressed by the facilities that have been developed for photography, micro-filming, and publication by photo-offset. These services are proving invaluable for re-publishing stocks destroyed in the flood of 1953, and also for copying or publishing other material. We note that the copying equipment owes much to the ingenuity of Dr. Wiltshire.

We approve the Director's plan for replacing obsolete optical equipment and consider, moreover, that the process should be accelerated so that each specialist can have a first-class modern microscope for routine work as soon as possible.

11. Culture Collection. We note with satisfaction the increased use that is being made of the culture collection and welcome the financial assistance towards its maintenance by the Department of Scientific and Industrial Research.

12. Publications. We are gratified by the growing demand for the Institute's publications as evidence that the Institute's acitivites meet a world-wide need; nevertheless we consider that continued expanding sales cannot be relied upon to finance the future needs of the Institute. The Review of Applied Mycology, has succeeded, by a number of editorial economies, in keeping pace with the increasing number of abstracts, without increase in size. We welcome the publication of the Review of Medical and Veterinary Mycology as a quarterly journal, covering a subject imtimately related to agriculture. We also endorse the publication of Commonwealth Phytopathological News.

The issue of the valuable Bibliography of Systematic Mycology is endorsed with the recommendation that in future it should appear half-yearly or even quarterly instead of annually as hitherto. We were gratified that considerable progress has been made with publication of monographs and other books and papers dealing with plant pathology and mycology. We learned with regret, however, that it has not yet been possible to start publication of the loose-leaf working sheets on pathogenic fungi discussed in the reports of the fourth and fifth conferences. If and when it is possible to produce them we recommend that they should be in the form approved at the last Conference.

13. Maps. We recommend that consideration be given to ways of increasing the information provided in the Distribution Maps of Plant Diseases.

14. Finance. Correct identification of pathogens is as essential in agriculture as in medicine, and the unrivalled taxonomic and information services provided by the Commonwealth Mycological Institute make an invaluable contribution to plant pathology and the control of plant diseases. In view of the world shortage of food we urge on the governments of the contributing countries the need for continuing financial support for the Institute.

11. Resolutions

The following resolutions were also adopted by Conference:

1. By the application of eradicative methods and measures, including legislative control, Australia has been able to eradicate several serious plant diseases and greatly to reduce the incidence of others. There are indications from Ghana that a similar policy applied to swollen shoot of cacao may eventually reduce this disease to neglibible proportions. The Conference urges that all countries should consider seriously the reduction of troublesome plant diseases by the use of eradicative measures (including seed and bud certification schemes) not only with newly introduced diseases but also with those that are well established.

2. The Commonwealth Mycological Institute has given active support to work on seed pathology through the publication of an annotated list of seed-borne diseases. The Conference welcomes the increased interest now being shown in the control of seed-borne diseases and the efforts towards improvement of the health of seeds at present being made by the International Seed Testing Association. It believes that there is a continuing need for reducing losses from seed-borne diseases, especially by encouraging the development of improved seed certification schemes, and the production of seed in areas where these diseases are at a minimum.

3. The Conference has noted the relatively slow progress being made in spite of much distinguished work in the control of many root diseases, particularly those of tree crops, where serious capital losses may be involved; it recommends increased research on this difficult group of diseases.

4. The Conference has noted with satisfaction the progress made in developing methods of recording accurately losses from plant diseases by the use of experimental methods. It considers that such investigations should be continued and expanded and that attention should also be given to ways of assessing and publicizing the benefits accruing from the increased application of control methods.

5. There has been increased recognition throughout the world of the importance of nematodes as agents in causing crop losses. The Conference is of the opinion that greater facilities should be provided for the training of specialists in nematology and also that some course work on nematology should be included in the training of every plant pathologist.

6. The Conference notes with satisfaction the ever broadening basis of research in plant pathology, but desires to emphasize the continued need for taxonomic research to ensure the accurate identification of the species of fungi and bacteria responsible for the immense losses caused by plant diseases.

12. Votes of thanks

Mr. E. F. Iton (Trinidad) proposed a vote of thanks to the authorities of the London School of Hygiene and Tropical Medicine for the use of their rooms and for the facilities provided by the refectory. He also thanked Mr. A. Perera for presiding at the Opening and Closing Sessions, the Director and staff of the Commonwealth Mycological Institute for their work in connection with the Conference, and the Resolutions Committee; and the Directors of the John Innes Institute, the National Vegetable Research Station, the Glasshouse Crops Research Institute, Rothamsted Experimental Station, and the Plant Pathology Laboratory, Harpenden, also Messrs. Plant Protection Ltd. and Imperial Chemical Industries Ltd, for the excellent arrangements made for the visits by delegates.

CONFERENCE

PROCEEDINGS

DIRECTOR'S REVIEW OF THE WORK OF THE INSTITUTE 1954-60

STAFF AND FINANCE - This Conference marks the termination of an epoch in the annals of the Institute and there are many changes to report in a time of rapid expansion. The period since the Conference of 1954 has seen the retirement of four members of the team which since the early days of the Bureau have, on the foundations laid by Sir Edwin Butler, raised an institution of utmost value to Commonwealth mycologists and plant pathologists, and accorded high prestige throughout the world. I refer to the well-known figures of my predecessor, Dr. Wiltshire, to Mr. Mason and the late Dr. Bisby, and to Miss Secker, the first abstractor, who set and maintained the high standard of abstracts in the Review of Applied Mycology which have been an example for all successive abstractors. The worth of their inspiration and labours is exemplified in the vigorous Institute of to-day, in the high standard of publications issued during the past forty years, and in the manifold assistance given to Commonwealth plant pathologists in the prevention of crop losses from diseases. As one who has reaped untold benefits from their work and advice I pay my earnest tribute.

Dr. Ellis has now taken charge of the Herbarium. Mr. Deighton has replaced Dr. Bisby and has also been elected in Dr. Bisby's place as United Kingdom representative on the International Committee of Nomenclature for Fungi and Lichenes.

Following Resolution No. 8 of the last Mycological Conference, the Review Conference of 1955 recommended the creation of additional A/B grade posts, but the funds provided were totally absorbed by the general monetary inflation and consequent salary increases which followed soon afterwards. Other costs, particularly of printing, also rose proportionately so that no funds were available to pay for extra staff. For the first three years of the present quinquennium, therefore, it was not possible to appoint additional mycologists, but sales of periodicals fortunately increased, and by careful spending sufficient money was accumulated to allow of the appointment of three new Mycologists in the past year.

The increase in revenue from publications was due largely to the issue of new publications and enhanced sales of back numbers and to a smaller extent to increased subscribers, and there is now apparent a levelling of the upward trend.

There are, however, certain urgent requirements of apparatus and equipment. Diagnosis of fungus species is to-day based on structures which can only be delineated by the use of efficient microscopes and there is pressing need for replacements of optical equipment in both the Herbarium and the Culture Collection, as will be seen in your inspection on Saturday. Furthermore, as explained later, a glasshouse is indispensable for work on tropical bacterial pathogens so that the continued provision of adequate funds is a prerequisite to continued efficiency.

BACTERIOLOGY - It is generally known that for a number of years Dr. Dowson of Cambridge University has acted as consultant to the Institute on bacterial plant pathogens and has made determinations of material submitted. He has now retired from the University and has not the facilities necessary for this work at his disposal. But requests for assistance from Commonwealth plant pathologists continue to be received, if anything in increasing numbers, so that the Executive Council agreed last year to the appointment of a Bacteriologist at the Institute. Dr. Hayward, then on the staff of the Colonial Microbiological Research Institute, Trinidad, was chosen. He is a fully trained bacteriologist who has turned his attention to plant pathogens and it is proposed that his main work should be on improved and more rapid methods of diagnosis as a preliminary to studies of plant bacteriological nomenclature. It is visualised that as a more practical gesture in the not too distant future the Institute may embark on the provision of phages and/or absorbed sera to Commonwealth countries in terms of Resolution No. 7 of the Conference of 1954.

The Ministry of Agriculture, Fisheries, and Food maintains the Commonwealth Collection of Plant Bacterial Pathogens at Harpenden, and as a working arrangement to avoid duplication it has been agreed that the C. M. I. will concern itself principally with pathogens of tropical crops, for it is upon these that advice is most frequently sought. For this purpose, early provision of a greenhouse at the Institute is absolutely essential: without one the work is already being handicapped.

Dr. Hayward is working with one technician and is now fully occupied in collaboration with overseas pathologists in the identification of the unknown pathogen of the serious cushion gall of cacao, and in studies of Pseudomonas solanacearum, for the identification of which he has devised a rapid staining technique, and of strains of Xanthomonas vasculorum in Mauritius and Réunion, as well as in routine identification work.

NEW BUILDING - On Saturday, there will be an opportunity for those who have not already done so to inspect the New Building which was occupied in 1955. It has infused new life into the work of the Institute as will be appreciated by those who knew the previous cramped conditions. Not only have the Herbarium and the Culture Collection been rejuvenated but a reorganization of the library has been made possible. The darkroom has provided facilities for urgently required photocopying and the production of photo-offset work, which has made many economies possible in printing publications and advertising matter and in reprinting back numbers of the Review of Applied Mycology and Mycological Papers. The work of reprinting has also received an impetus from the valuable assistance given by Central Sales, so that substantial stocks of the complete sets destroyed in the flood of 1953 are again available.

Microfilming has increased and copies are made of all papers abstracted in the review journals or containing diagnoses of new species, not filed in the library. The production of microcards of diagnoses has, unfortunately, had to be discontinued for technical reasons.

More laboratory and library facilities for visitors are now available and for the time being it is no longer necessary to refuse requests to study at the Institute because of lack of accommodation.

However, one large room is now allocated for bacteriology and a second will be required, another room is occupied by Fusarium cultures, the Culture Collection is rapidly expanding, and the library and store room will be filled before long. Already the need for an extension can be visualized.

PUBLICATIONS - The issue of established periodicals has continued but the ever increasing volume and scope of plant pathological literature and the increased cost of printing and postage have called for certain amendments in the abstract journals, including the introduction of directory notices and internationally recognized abbreviations, the rearrangement of pages, and consolidation of the annual index, so that more abstracts are now appearing on less pages without, it is hoped, any decrease in essential information.

In order to ensure its regular appearance the Review of Medical and Veterinary Mycology has from March 1958 been issued as a quarterly journal. This change was widely advertised and the response has been an increase in subscribers of 113 from 39 countries. The mycoses of man and animals are now receiving far more attention from medical and veterinary workers than hitherto and the demand for this Review is likely to increase. As a corollary, the literature on the subject is expanding rapidly so that an increase in the size of the Review must be anticipated in the near future.

A session has been arranged at this Conference for the discussion of the problems associated with abstract journals.

Expansion of mycological work throughout the world has been reflected in greatly increased entries in both the bi-annual Index of Fungi and the annual Bibliography of Systematic Mycology. A cumulative index in 2 parts of Petrak's Lists for 1940-49 was issued in 1956-57, and some 4,000 species omitted from the originals are now being compiled for publication as a supplement in the near future.

Minor re-organization of the work of the Herbarium and appointment of extra staff to deal with routine identifications has allowed of more specialization by the experienced mycologists. It has thus been possible to issue 20 Mycological Papers, with others in the press. The total number issued to date is 77.

Two Distribution Maps of Plant Diseases a month have appeared regularly, including revisions of the more important pathogens. Total number issued to date is 376. An index and list of amendments and corrections (1-350) was distributed free this year.

Two new series of publications have been issued since 1954. Phytopathological Papers, of which 3 have been published with 2 more in preparation, have so far been confined to monographs. The Commonwealth Phytopathological News commenced publication as a 16-page quarterly news-sheet in January 1955 in conformity with Recommendation No. 10 of the 1954 Conference and has appeared regularly since. Reports indicate that it has been well received but the number of subscribers (416 in 1959) is disappointingly small. This appears to be due to the reluctance of plant pathologists to order private copies and to rely on official library copies. There is no doubt that it is seen by a wide circle of readers in the agricultural world. It is hoped that the Conference will find time to discuss in committee ways of making this news-sheet self-supporting.

A revised list of common names of virus diseases used in the Review of Applied Mycology was issued free as a supplement to Vol. 36 of that journal.

The compilation of specialised bibliographies has received much consideration but staff has not been available for this work until recently. With the appointment of a trained librarian the preparation of a bibliography of lists of plant diseases in the Commonwealth is well advanced, and a start has been made on collating plant pathological literature.

Preliminary work has also commenced on a cumulative index of the Review of Applied Mycology, vols. 1-40 on the same lines as that for Petrak's Lists.

Comments of delegates of these new ventures will be most welcome.

HANDBOOKS - Despite the hopes expressed in Recommendation No. 3 of the 1954 Conference only limited success has crowned attempts to produce more handbooks on diseases of tropical crops. My book on 'Tobacco Diseases with special reference to Africa' appeared in 1956 but 'Diseases of Sorghum' by Dr. Tarr is not quite ready for press and is unlikely to be published before 1961. A further book, 'Diseases of Cacao', is being written by Mr. Thorold, but date of publication cannot yet be foreseen.

A fifth and much enlarged edition of Ainsworth & Bisby's 'Dictionary of the Fungi' is, however, now in the press, and a handbook on the methods and techniques employed at the Institute, with a short factual history by Dr. Wiltshire, has appeared this month in response to many requests received from visitors to the Institute. It is a co-operative effort on the part of the scientific staff as a gesture of appreciation of Mr. Mason's influence on taxonomic mycology in the past 40 years.

In 1958, in collaboration with the International Seed Testing Association, the Institute published 'An Annotated List of Seed-borne Diseases' by Drs. Mary Noble, Paul Neergaard, and J. de Tempe, of which 214 copies have been sold, in addition to 1,000 copies supplied at cost to the I.S.T.A.

HERBARIUM - The Herbarium now comprises over 80,000 specimens, an increase of 25,000 since 1954, and the identification service is handling around 4,000 incoming specimens a year. These numbers are tending to increase now that more mycologists are available for specialized work. The duplicate collection is being steadily built up for the use of visitors and for the preparation of exsiccata. Indexing the rusts according to the new code of nomenclature is now complete, and about 100 slide preparations of common saprophytes which have animal or human pathologic forms have been disposed in their appropriate jackets.

The policy of whenever possible growing fungi under examination in culture and depositing the dried cultures for future reference is proving invaluable for identification purposes and the techniques are being constantly improved.

Dr. Ellis continues to specialize in the tropical Hyphomycetes, Mr. Deighton in Uredinales, Meliolineae, the genus Cercospora, and African fungi in general,

Dr. Booth is taking up the genus Fusarium, for which there has not been a specialist at C. M. I. since Mr. Ashby retired, and Miss Waterhouse continues her studies of the Phycomycetes, particularly Phytophthora. The newly appointed Mycologists have also chosen certain groups of fungi for special study.

The Culture Collection is expanding rapidly, the number of cultures maintined increasing from 1, 783 (1954) to 2, 821 (1959). The total number distributed rose from 1, 223 to 1, 802 and the sales from £279 to £755. As a result of the Government policy of greatly expanding the training of technologists, many of whom are microbiologists, increased demands have been made on the Culture Collection by teaching and research establishments as well as by industrial firms engaged in biological processes. It has been found that many teachers of microbiology are not fully conversant with mycological techniques and the help of the Institute is being increasingly sought. In this connection it is a pleasure to acknowledge the financial assistance provided by the Department of Scientific and Industrial Research in a grant of over £2, 000 a year, which I am given to understand unofficially is likely to be considerably increased in 1961.

OVERSEAS CONTACTS - At the request of the Colonial Office the Director paid a number of visits to overseas territories to advise on certain problems. In 1955, he spent 6 weeks in Nyasaland drawing up a research project on tobacco leaf spot due to Alternaria longipes. In 1956, he visited Nigeria to advise on the control of tobacco leaf curl, and Malta to enquire into plant protection requirements in the island. In 1957 and 1958, he visited East Africa as representative of the Secretary of State for the Colonies to the East African Agricultural Research Council and toured research stations in the High Commission territories. As a result, research was intensified on Armillaria root disease of tea in Kenya (a paper is being presented to this Conference), wither tip of limes in Zanzibar (subsequently taken up by the Pool), stem pitting of coffee (which is not yet solved), and black stem rust of wheat (initiation of epidemiological studies). He also arranged for Dr. Wickens and Mr. Rayner to come to the C. M. I. to write up their researches on cotton and coffee diseases. In 1959, at the request of the Government of Canada he toured agricultural research centres, making contact with all personnel engaged in research on mycology and plant diseases. At each centre he gave an illustrated talk on the work of the Institute and valuable discussions ensued.

POOL OF PLANT PATHOLOGISTS - Expansion of activity can also be reported. In December 1954, Dr. Wheeler was appointed and later accompanied Dr. Hopkins to Nyasaland to investigate a serious outbreak of Alternaria longipes leaf spot which was endangering a project of the Colonial Development Corporation for the extension of flue-cured tobacco cultivation. This work was completed in 1957 and recommendations made which successfully controlled the disease. He then went to Malta, and spent six months on a survey of crop diseases in the island, about which little was known before. On the completion of this work he proceeded to Zanzibar to investigate wither tip disease of limes which had become the limiting factor in the production of this crop. He has obtained economical control with phenyl mercury nitrate sprays and is returning in August to confirm his findings.

On the completion of his researches on broad bean wilt in Cyprus, reported to the last conference, Mr. Altson went to Sarawak to continue the preliminary investigations, initiated by Prof. N. F. Robertson, of a serious foot rot of black pepper. Unfortunately, he had a breakdown in health which necessitated his return to England, where he undertook supervision of the Pool. He was succeeded by Mr. Paul Holliday who, working with Mr. W. P. Mowat of the Department of Agriculture, Sarawak, found the pathogen to be a species of Phytophthora as yet unnamed. A report of this work, written by Mr. Holliday, is being presented by Mr. Mowat later in the Conference. The etiology of the disease is complicated and no commercial success has been obtained by the use of fungicides, but Mr. Holliday has introduced selected varieties from Indonesia and India showing field resistance, which, combined with improved cultural methods, offer hopes of a solution to the problem.

INTER-AFRICAN PHYTOSANITARY COMMISSION - The Director is a member of the Committee of Information of the Commission and Mr. Altson acts as Liaison Officer for the Institute. The principle work of the Commission since its first annual meeting in 1956 has been the formulation of uniform plant importation.

legislation for all states in Africa south of the Sahara. This has necessitated the compilation of lists of known fungal, bacterial, and virus diseases of crops in Africa and of similar lists of diseases not yet recorded in Africa. As no attempt in the past has been made by most African territories to produce such lists literature research on a large scale has had to be undertaken by the Liaison Officer. Considerable headway has been made by the Commission towards its objective and close co-operation has been maintained between the Institute and the Scientific Secretary of the Commission. The expenses incurred by the Institute are met in full by the Commission.

ADVISORY WORK - In addition to routine work the Institute is asked to advise on a number of disease problems of tropical crops, principally by the Colonial Office. For instance (as well as those already quoted):

Mr. Deighton continued to collaborate with Dr. Cammack in Nigeria in a statistical analysis of Puccinia polysora throughout the world and the result of this work will be presented to the Conference.

Cushion gall of cacao has become a disease of major importance in South and Central America, and has recently been found in West Africa, where its occurrence is, so far, rare. The disease has been readily transmitted mechanically and by insects from diseased to healthy plants but the pathogen, suspected to be a bacterium, has so far escaped identification. In view of the potential danger of the disease Dr. Hayward is collaborating with plant pathologists in the field in an endeavour to determine the causal organism.

For many years the sugarcane industry of Mauritius has been stablized by the cultivation of varieties resistant to gumming disease due to Xanthomonas vasculorum. Recently, these varieties grown in Réunion have succumbed to the disease and it is feared that a more virulent strain of the bacterium may have arisen which might be introduced to Mauritius. Dr. Hayward has done preliminary work on this problem and was planning to visit the areas concerned when the damage caused by the recent severe hurricanes made postponement necessary.*

The serious coffee berry disease which has caused heavy losses of crop in Kenya has defied complete control for a number of years, but intensive research in East Africa with fungicidal sprays has recently made promising progress.

Black pod due to Phytophthora palmivora is the cause of major losses of cacao in West Africa and elsewhere. Breeding for resistance has been handicapped by lack of suitable inoculation techniques and knowledge concerning the infection potential of different strains of the fungus. The Institute has assisted the field workers by laboratory experiments and advice on cultural characteristics.

Pseudomonas solanacearum is a ubiquitous pathogen causing bacterial wilt of a wide range of tropical crops but is often difficult to identify accurately. Dr. Hayward has developed a simple staining technique, which if proved universally, will facilitate rapid determination.

ANIMAL MYCOSES - The Institute has also collaborated in work on mycotic diseases of animals. Facial eczema of sheep has caused heavy mortality for many years in New Zealand and the cause has remained undetected. Recently, New Zealand workers have traced the origin to toxins produced by the fungus generally known as Sporidesmium bakeri and Dr. Ellis has assisted in establishing the identity of the fungus. Dr. Ainsworth has also collaborated with Mr. P. K. C. Austwick of the Veterinary Research Laboratory, Weybridge, in the production of an authoritative book on animal mycoses, which is in great demand.

RECENT PROGRESS IN PLANT PATHOLOGY - Considerable advances have been made in the science of plant pathology during the past six years and it is gratifying to see much progress being made in lines of research to which attention was called at the last Conference. Seed pathology has made great strides through the International Seed Testing Association and under the impelling influence of Dr. Neergaard and his colleagues. They will tell us all about it at a special session. More accurate assessment of crop losses was also urged by the last Conference and Mr. Large, Mr. Ogilvie, and Mr. Thorpe will recount the astonishing progress that has been made since then. The introduction of the Hirst spore trap and the

*Since this report was presented Dr. Hayward has visited Mauritius, Réunion, Madagascar, and Natal to study the disease.

researches on airspora pioneered by Dr Gregory and Mr. Hirst combined with the conception of infection periods have revolutionized ideas on fungicial spraying. The development of low volume spraying and the analysis of droplet spectra, the practical consideration of which can probably be traced to the joint meeting of the Mycological and Entomological Conferences of 1948, are now bringing further modifications to our ideas on the uses of fungicides and insecticides.

There has been a distinct change of outlook in recent years regarding the causation of disease, for the new biochemical techniques, particularly chromatography, have opened up an enormous field of research in host-parasite relations. There are indications in some quarters that the parasite is being obscured by its own by-products and there is a tendency to replace the traditional plant pathologist, with his knowledge of fungi and bacteria, by the chemist. In moderation this is advantageous but the change should be one of co-operation and not of substitution. For the research pathologist will always require the ability to recognize his pathogen in whatever guise he may find it or assuredly he will at some time or other follow the wrong path indicated by inaccurate identification. It has happened many times in the past and will be repeated so long as the pathologist is unsure of his species.

A welcome trend, which is becoming progressively more noticeable, is a lessening of the clear-cut division between pests and diseases. This particularly is emphasized where methods of control are concerned. The prevention of many virus diseases depends on the control of the insect vector, and the plant pathologist, passing through a period of metamorphosis, finds himself turned into an insect ecologist. In the same way, other diseases are largely resolved by the control of insect pests as exemplified by the effects of capsid spraying on die-back and swollen shoot of cacao. And who as yet can apportion the parts played by nematodes, fungi, and bacteria in the causation of root disease, about which it is hoped there will be much said in discussion? To my mind this trend is all to the good and in the near future we shall see the evolution of the plant protectionist with a far wider outlook on his problems than that of the mycologist, the plant pathologist, or the entomologist.

This increased breadth of outlook is already reflected in the abstract journals, and these will continue to be adjusted to the needs of their readers, which are constantly under review by the Editor and his staff. An opportunity for full discussion will be provided in the session on information services.

In conclusion, I wish to express my thanks to the assistance given and generous facilities provided by the Director and staff of the Royal Botanic Gardens, particularly, Dr. C. E. Hubbard, Keeper of the Herbarium and Dr. R. W. G. Dennis, and for kindly providing the Mounters' Hut for our meeting on Saturday. I also wish to pay tribute to the enthusiasm and loyalty of my own staff without which the progress reported could not have been achieved.

Finally, I must refer to the untimely death of Dr. G. R. Bisby, a short time after his retirement. There is no need for me to refer to his ability and standing as a systematist, for his wide understanding of taxonomic principles did much to establish the Institute as a centre for systematic mycology.

July 15 morning

Information Service for Plant Pathology

Chairman: G. G. Samuel

THE REVIEW OF APPLIED MYCOLOGY

G. C. Ainsworth
Commonwealth Mycological Institute

In an attempt to analyse the scope of the Review of Applied Mycology and to elucidate trends in the literature of plant pathology during the last 30 years the contents of five representative volumes of the Review were examined in greater or less detail. From the primary analysis of these volumes as summarized in Table 1 it is clear that while between 1925 and 1958 the annual number of publications noticed has doubled, the number of pages in the Review has remained constant. This calls for explanation.

Table 1

General analysis of five representative volumes of RAM

Year	1925	1930	1939	1950	1958
Volume	(4)	(9)	(18)	(29)	(37)
Pages					
Abstracts	768	816	832	640	768
Index					
Authors	8	10	13	13(2 col./p.)	16 (3 col./p.)
General	92	112	98	83	102
Total	100	122	111	94	118
Total	868	938	943	734	886
No. Authors	1022	1228	1665	1805	3309
No. Abstracts	1447	1626	1838	1773	3070
Page size	1	1	1	1.2	1.2
Abstracts/Page	2.3*	2.4*	2.6*	2.8	4.0
	*adjusted to larger page				
Subscription price per Abs. (d)	0.10	0.13	0.20	0.27	0.27

Economies

The major economy was the 20% increase in the type area per page effected during the war by encroaching on the margins, because of the shortage of paper, and this territory has been permanently occupied, due to the increased cost of paper. Further, the 1939 volume contained 123 abstracts (equivalent to 40 pages) on medical and veterinary mycology, a topic now covered by an independent quarterly review and similarly, certain 'general' papers have been transferred to the independent annual Bibliography of Systematic Mycology which provides a background to the Index of Fungi. Finally, in 1958 a small saving was made by reducing the titles of the monthly parts and a major saving by the introduction of a number of standard abbreviations and by treating the title of the paper as part of the abstract.

In 1960, a few more pages have been gained by abbreviating the addresses of the places from which the papers have originated. The 768 pages of abstracts in 1958 are therefore equivalent to approximately 1,000 pages of the pre-war format. Similarly, various economies have been made in the index by printing the authors names in three columns per page instead of in two and by a reduction in duplicated entries of host-specialized pathogens.

The abstracts have always been written in a narrative rather than a telegraphic style and condensation from an average of rather less than half a page per abstract to approximately a quarter has been helped by a tendency for authors to collaborate and to write shorter papers (see Table 2). It has also been helped by giving borderline papers or reports of specialized work of limited appeal to practising plant pathologists brief 'directory notices'.

Table 2

Samples of 100 journal articles from RAM for:

	1925 (4)	1930 (9)	1939 (18)	1950 (29)	1958 (37)
Authors/Paper	1.19	1.33	1.37	1.43	1.48
Pages/Paper	12.42	12.38	14.14	9.86	7.15
Summaries in a 2nd language	3(1)*	3(1)	5(3)	9(7)	16(15)

* number in English

In passing it may be noted that the rise in the subscription price per abstract from 0.1d. in 1925 to 0.27d. in 1958 is well below the general rise in world prices.

Amount of literature

The exact amount of the current annual output of plant pathological literature is a matter for speculation. The Bibliographie der Pflanzenschutzliterature for 1951 (the most recent) lists 12,500 items derived from a survey of some 3,000 periodicals. That survey includes pests but has perhaps 5,000 references bearing on plant pathology as generally understood derived from 2,000 publications.

Scatter of the literature

The scatter of the literature is certainly increasing but as a compensation more papers have to be noticed from a few of the major journals. Approximately 800 periodical publications are regularly scanned but papers from many more are noticed on occasion. Not all contain relevant articles in any one year and the 3,070 abstracts in 1958 came from 530 different journals, 59 books, and 71 reports - a total of 660 publications. Further evidence of the scatter was given by random samples of 100 journal articles from each of the 1925, 1939, 1958 volumes which included 76, 68, and 66 different journals, respectively; only 3 journals (Phytopathology, Plant Disease Reporter, Zeitschrift für Pflanzenkrankheiten), however, being common to the three series.

Languages

The language scatter is also showing a tendency to increase, but a higher proportion of papers is being published in English, German, Russian, French, or Italian (see Table 3). French is losing ground, Italian and Russian are gaining ground and while publications in English have shown little change the data in Table 2 suggests that there is a marked increase in the provision of English summaries in papers in foreign languages.

Table 3

Languages - according to numbers of abstracts

	1925 (4)	%	1939 (18)	%	1958 (37)	%
French	148	(10.2)	106	(5.8)	142	(4.6)
Italian	38	(2.6)	77	(4.1)	126	(4.1)
German	215	(14.8)	236	(12.8)	263	(8.6)
Dutch	45	(3.1)	46	(2.5)	45	(1.5)
Scandinavian	20	(1.4)	25	(1.4)	27	(0.9)
Spanish	18	(1.2)	20	(1.1)	33	(1.1)
Portuguese	0	(0.0)	10	(0.5)	27	(0.9)
Russian	19	(1.3)	48	(2.6)	175	(5.7)
Czech	6		7		20	
Polish	4		7		15	
Serbo-Croat	0		3		27	
Bulgarian	5		5		22	
		(1.0)		(1.4)		(3.8)
Romanian	0		3		11	
Hungarian	0		1		16	
Estonian	0		0		2	
Latvian	0		0		2	
Japanese	7	(0.5)	27	(1.5)	18	(2.3)
Chinese	0		0		52	
English (by difference)	922	(63.8)	1217	(66.3)	1947	(63.4)

Content

Pathogens. The contents of volumes of the Review for 1925, 1939 and 1958 are summarized in Table 4; the proportion of papers on fungal diseases has remained approximately constant and that on bacterial diseases has shown a slight decrease. Virus diseases have received much more attention, but Thornberry's (Plant Dis. Reptr, 43:371-373, 1959) estimates for the years 1947 to 1956 of the percentage of abstracts on virology in the Review of between 19.9 in 1948 and 33.2 in 1956 would appear to be on the high side because the numbers of abstracts on all diseases was consistently underestimated. Table 5 gives an analysis of the numbers of hosts and pathogens recorded in the index for 1958, which shows a rather similar pattern for viruses, bacteria, and fungi and emphasizes the frequency of imperfect fungi as pathogens.

Table 4

Interest in various aspects of plant pathology from numbers of abstracts

Plant Pathology	1925 (4)	%	1939 (18)	%	1958 (37)	%
General	174	(12.8)	133	(7.9)	197	(6.7)
Fungal diseases	826	(61.2)	1001	(59.9)	1755	(59.2)
Bacterial diseases	94	(6.9)	95	(5.7)	145	(4.9)
Virus diseases	84	(6.1)	257	(15.3)	527	(17.8)
Non-parasitic disorders	62	(4.6)	110	(6.6)	107	(3.6)
Fungicides	88	(6.5)	59	(3.5)	204	(6.9)
Legislation	24	(1.8)	24	(1.4)	17	(0.6)
Total Plant Pathology	1352	(93.4)	1679	(92.4)	2952	(97.6)

(Analysis by E. B. Martyn)

Table 5

Hosts and pathogens in the 1958 Index

		%	
Hosts			659
Pathogens			
Viruses	332	(19.2)	
Bacteria	96	(5.5)	
Fungi			
Phycomycetes	91		
Ascomycetes	289		
Basidiomycetes	133		
Rusts	111		
Smuts	30		
Fungi Imperfecti	634		
	1,288	(75.3)	
			1,716

Crops. The attention paid to the diseases of different crops was estimated by measuring the lengths of the index entries under 63 major crop plants. Table 6 summarizes the results according to the type of crop and Table 7 summarizes the results for certain individual crops The relative attention paid over the years to the different types of crop appears to have remained remarkably constant. There has perhaps been slightly less relative attention to cereals in recent years and slightly more to vegetables. Ornamental plants have certainly received more attention. Among individual crops the increased attention to rice, citrus, lettuce, carnation, and chrysanthemum and the decreased interest in rubber and the vine are of interest. The current interest in tobacco, tomato, and beans is complicated by the frequent use of these plants in virus studies.

Table 6

Interest in different types of crops as percentages derived from lengths of index entries

	1925 (4)	1930 (9)	1939 (18)	1950 (29)	1958 (37)
Tropical (15)	26.5	30.4	27.2	26.7	26.9
Cereals (5)	16.0	15.2	11.8	13.3	13.7
Fruit (10)	18.1	13.8	13.7	11.1	14.2
Vegetables (18)	27.1	26.1	31.2	35.9	32.2
Ornamentals (4)	1.4	1.9	1.9	2.7	2.9
Trees (8)	5.1	6.9	8.8	5.8	6.2

Conclusion

The Review of Applied Mycology has never attempted completeness of cover. It has always tried to select the more important recent literature and has always aimed at supplying workers with restricted library facilities with sufficiently full abstracts to enable them to keep informed of the progress of current work. This it will continue to do.

In conclusion it is of interest to quote the view recently expressed by B.C. Vickery (Unesco Bull. for Libraries 13;252, 1959) who wrote:

"The basic problem of documentation is not mechanical, but human: the amount of literature to be read is increasing exponentially, and the time anyone has for reading it remains the same, therefore a smaller proportion of what is written is read by any one person. We do not want to be able to retrieve more documents for each reader but to retrieve more selectively."

We do not want to abstract more papers but to abstract more selectively.

Grateful acknowledgement is made to all those members of the Institute staff who helped with the analysis, and especially to Mr. A. Barge, Mr. & Mrs. R. Buhler, Miss E. Goloczynska, Dr. D. G. M. Muller, and Mr. A. Seymour, and to Mr. E. B. Martyn.

Table 7

Interest in some individual crops as percentages derived from lengths of index entries

	1925 (4)	1930 (9)	1939 (18)	1950 (29)	1958 (37)
Wheat	6.5	6.8	4.5	4.5	5.7
Maize	2.3	2.8	2.5	3.0	3.2
Sorghum	0.7	1.1	2.1	2.0	1.1
Rice	0.6	0.5	1.1	1.7	2.7
Citrus	3.5	2.6	3.3	3.8	4.7
Coffee	1.2	2.3	1.3	1.3	1.4
Rubber	3.5	3.3	1.5	1.2	1.0
Tea	1.0	1.4	1.0	0.7	0.8
Tobacco	3.9	4.3	4.3	5.9	5.7
Potato	9.2	8.4	9.0	8.5	8.0
Tomato	3.3	3.7	4.2	5.5	5.5
Cucumber	1.1	0.9	2.0	2.7	1.9
Beans	1.4	1.9	2.7	3.7	3.9
Lettuce	0.7	0.8	0.7	0.6	1.1
Carnation	0.3	0.5	0.4	0.9	1.1
Chrysanthemum	0.3	0.4	0.5	0.8	1.0
Vine	4.1	3.4	2.4	2.1	1.7
Olive	0.4	0.1	0.4	0.8	0.4

THE REVIEW OF APPLIED MYCOLOGY AND OTHER C. M. I. INFORMATION SERVICES

Grace M. Waterhouse
Commonwealth Mycological Institute

The operative word in the present treatment of R. A. M. is 'selective'. It is and must be selective. The first move in this operation is done by weeding out the incoming literature before it reaches the abstractors. Then the material given to the abstractors bears an indication of the way in which it is to be treated. There are a few basic principles on which we work:

1. We try to select the new material and leave out previously published information and well-known facts. In this our references back to previous abstracts help both us (to make sure the information has not been repeated) and the reader (to find the previous information).

2. We confine ourselves for the most part to applied aspects, i. e. to organisms, plants, diseases, and materials of economic importance, or to those which have a close bearing on these aspects.

3. We rule out very specialized aspects of applied mycology and plant pathology which do not appear to have an immediate interest for workers in these fields, e. g. details of narrow physiological studies of fungi in vitro; chemical properties of individual viruses.

4. Although the largest field is applied mycology we tend to leave out industrial mycology, particularly that of yeasts, wine making, antibiotic production, etc.

Further selection is a little more difficult, and over this the editorial staff do not always have the same ideas. The most difficult decisions are over lengthy reports of international congresses, abstracts of papers read at meetings of societies, and the like. We try to give results, control methods, and techniques in adequate detail.

The flood of literature that pours into C. M. I. is also put to other uses.

1. The geographical aspect - the Index of R. A. M. does not include countries as headings. Therefore, if you wish to find out something about a particular country you can only do it under pathogen or host or quarantine or reports. This geographical aspect is catered for to a certain extent by the Distribution Maps of Plant Diseases (nearly 400 to date) each showing the reported world distribution of a particular disease (pathogen).

2. There are also lists of diseases for particular territories (about 15 so far) which are published as Mycological Papers from time to time. Here mention might be made of lists being compiled by Mr. Altson for the African Phytosanitary Commission; these are of the virus, bacterial, and fungus diseases recorded in the territories south of the Sahara, each with a complementary list of important diseases not yet found in these countries. This will be to us a very useful compilation and if we get a question about Africa we can often obtain an answer very quickly from these lists, whereas it would take some hours hunting through the indexes of R. A. M. Similar lists for the other continents would be extremely useful.

3. In the field of systematic mycology, most of the fungi not of economic importance are left out of R. A. M. A list of titles only (about 1,000 a year), about half of which are noticed in R. A. M., goes into the Bibliography of Systematic Mycology. It would be useful if these were annotated or had short abstracts. Coupled with this is the Index of Fungi which contains the names of all new taxa published.

4. Any items in the literature suitable for the Review of Medical and Veterinary Mycology are dealt with at the same time.

5. Many questions by letter and by phone are answered - a useful service not appearing in print - by reference to the sources of information mentioned above.

Discussion

R. W. RAYNER (Kenya) made a plea for the integration of the vast mass of knowledge at present most efficiently catalogued by the C. M. I. information service. This service, as it stands, is particularly useful if one's interest is in a given disease, but if information is required on principles or techniques it is not so easy to obtain a clear picture. In the past this integration has either been attempted by the text-book writer or been left to the individual worker. Textbooks are often too general and quickly become out-of-date, while with the exponential increase in the amount of literature and greater calls on his time the matter can no longer be left to the individual. The problem is particularly acute in the Colonial and new Commonwealth countries, where there is little opportunity for discussing problems with other workers.

Consideration should now be given to the production of review articles, such as: (1) up-to-date surveys of particular diseases or groups of diseases; their nature, characteristics, biology, epidemiology, control, etc.;(2) surveys of plant pathological problems; methods of control, methods of assessing disease incidence statistical designs appropriate to fungicidal trials, mode of action of fungicides, etc., (3) general accounts of advances in other scientific disciplines.

G. G. SAMUEL (Chairman) asked for the general feeling of the meeting on reviews and suggested that one review article might appear in each volume of R. A. M.

S. A. J. TARR (U. K.) considered that the publication of reviews is not the proper function of an abstracting journal and that they should appear separately, published at irregular intervals as the need arises. While reviews might well be published by the C. M. I. they should not form part of R. A. M.; the essence of R. A. M. is that it is a handy abstracting journal and it would not be desirable to enlarge the volumes.

P. K. C. AUSTWICK (U. K.). pointed out that reviews are now published by the Commonwealth Bureau of Animal Health in Veterinary Reviews and Annotations and thought that there was a need for a separate journal for reviews in the field of plant pathology.

E. C. LARGE (U. K.) thought that the inclusion of review articles in R. A. M. would involve the reviewer in making invidious selections of abstracts. It would be better to have a heading in the R. A. M. index for review articles, clearly indicating where they may be found.

W. G. KEYWORTH (U. K.) agreed that a review should present a critical summary of available information and would best be contributed by specialists to a publication separate from R. A. M.

B. L. CHONA (India) thought that while R. A. M. was excellent as it stands, it could be improved by the publication of a selected list of review articles as a supplement.

D. RHIND (U. K.) feared that the Commonwealth Institutes and Bureaux would necessarily give due weight to the interests of their major contributors, and that review articles would consequently deal mainly with subjects of interest to the maximum number of readers, i. e. to those in temperate regions.

G. G. SAMUEL said that the need of tropical workers is great and must not be ignored. He hoped that they would be called upon to provide some of the reviews.

C. J. MAGEE (Australia) also drew attention to the less favourable position of plant pathologists in the tropics as compared with those in Australia and Canada for whom the literature of the world was more readily available. He felt that reviews should be kept separate from R. A. M., which should keep its present title. The problem should be approached cautiously and every review must be

written by a specialist. It is the use of professional abstractors which has made R.A.M. so excellent; specialist reviewers cannot be produced like professional abstractors.

C. L. A. LEAKEY (U.K.) considered that an annual review of advances in plant pathology would be most useful and also made a plea for a fuller index to R.A.M., as at present it is very easy to miss useful information concealed in papers in which one otherwise has no particular interest.

MISS M. NOBLE (U.K.) said that she had come to the conclusion that more detailed information in R.A.M. index would be very useful. For example, notice of accepted changes in nomenclature could be given there - 'changes in Herb. IMI' are listed in C.P. News, but it is perhaps not generally realised that these are also adopted in R.A.M. If any subject, such as industrial mycology, ceases to be reviewed, a statement to that effect could also be made in the index. She added that the title of R.A.M. no longer reflects its actual contents and suggested that it should be expanded to include plant pathology.

W. G. KEYWORTH thought that it would be a great pity to alter the initials R.A.M.

J. E. CROSSE (U.K.) and S. D. GARRETT (U.K.) both agreed and thought that there would have to be very strong reasons to justify a change.

P. H. GREGORY (U.K.) said that R.A.M. is in fact a review of plant pathology, or plant pathology abstracts, and that the title is therefore misleading; it does not claim to contain abstracts of industrial mycology or medical mycology. It has shifted in emphasis and its title should be changed. He thought that reviews should go into a separate journal, and suggested something on the lines of Biological Reviews.

G. G. SAMUEL also believed that the name should be changed to one more descriptive of its actual contents and thought that the rising generation of plant pathologists would soon get used to new names.

E. R. WALLACE (U.K.) supported the demand for a fuller index for R.A.M., and made a special plea for the indexing and cross-indexing of substances such as fungicides.

J. C. F. HOPKINS (U.K.) said that it was the C.M.I.'s policy to use British Standard names wherever possible.

MISS G. M. WATERHOUSE (U.K.) added that whereas some workers use pure chemicals others use the same chemicals in proprietary compounds. In R.A.M. the actual fungicide used is quoted.

W. G. KEYWORTH asked whether it would be possible to provide a more complete index to each monthly part. More detail had been given in the past and he wondered if it would be possible to return to this practice. For example, it was sometimes difficult to find references to Verticillium in the monthly issue.

G. G. SAMUEL did not think that the monthly analysis of contents had ever contained more detail.

G. C. AINSWORTH (U.K.) said that while there used to be an author index and an index to paper titles, there was no subject index before 1939.

G. G. SAMUEL wondered if the shorter abstracts now included in R.A.M. were designed merely to draw the attention of workers to papers with the idea that they would consult the originals. The old idea was that abstracts should be as full and as long as possible. Did any workers abroad find these shorter abstracts a difficulty?

D. RHIND did not think it mattered if papers in English were given short notices, but papers in the more difficult languages should be given fuller abstracts.

R. W. RAYNER said that the main function of R.A.M. is to draw attention to what has been published. If the original papers are quite easily obtainable short abstracts are quite adequate.

15 July afternoon

Taxonomy in relation to plant pathology

Chairman: Dr. G. H. Cunningham

THE STATUS OF TAXONOMIC MYCOLOGY IN PRESENT DAY PLANT PATHOLOGY

A. J. Skolko
Canada Agriculture Research Branch, Ottawa

In 1959, "Plant Pathology Problems and Progress 1908-1958" was published to commemorate the Golden Jubilee of the American Phytopathological Society. It contains the text of a number of invited addresses on the historical and developmental aspects of plant pathology and a comprehensive series of international symposia intended to cover "the many facets of plant pathology". As an historical review and as a portrayal of present interests and trends in phytopathological research you will, I believe, agree with me that it has fulfilled its purpose admirably. The symposium sections of this volume clearly indicate the tremendous change that has taken place in plant pathological research in the last fifty years and particularly in the last thirty years. The symposia are grouped under such subjects as the physiology of parasitism, the mechanisms governing pathogenicity and disease resistance, the mode of action and chemistry of fungicides, the structure and multiplication of plant viruses, etc. Clearly, the plant biochemist, the plant physiologist, the geneticist, physicist and chemist have elbowed the classical mycologist from the centre of the phytopathological stage. From its revered position as father of plant pathology, taxonomic mycology has declined to the role of grandfather of plant pathology, and indeed seems to be in danger of imminent demise.

Let me recall some of the events of this critical thirty years of mycological dilution as seen from the pedestrian side of the phytopathological super-highway, or, perhaps, more correctly, from around the corner of a Canadian mycological herbarium case. The sentiment expressed so eloquently by Whetzel (1928) was almost prophetic when he said, "There must be no evasion of the fact that the diseased plant is the central figure in the phytopathological drama ... The disease concept must condition and rationalize all other concepts of our science .... The causal organism, where such is involved, must be relegated to its distinctly secondary role." Whetzel was not the first to enunciate such a view but it became the battle cry that was taken up by many who followed. Its echo still reverberates strongly, for Horsfall and Dimond (1959) refer to the golden age of mycology in these words. "For a hundred years, more or less beginning in the early part of the 19th century, when mycology dominated the scene, diseases came to be equated with microbial pathogens and diseases were thus classified on the basis of causal organisms.". The theme that the diseased plant is the primary consideration of plant pathology is the basis of organization of volume 1 of the series of text books edited by Horsfall and Dimond.

Even the most devout mycologist must concede that thirty years ago phytopathology was at the crossroads. Mycologists had done a heroic job in providing at least the temporary solution of many urgent plant disease problems but the importance of other microbial pathogens, the bacteria, nematodes, and viruses, was apparent. Also the rapid advances in knowledge and techniques in plant physiology, plant biochemistry and genetics, and cytology provided the tools for more pentrating studies of the interaction of host and pathogen, of antibiosis and of chemical fungicides. The sophisticated physical and chemical instrumentation developed during this period furnished the means, for example, for not only the isolation and characterization of plant viruses, but also investigation of their physical and chemical organization. While applauding these achievements, mycologists, and especially taxonomic mycologists, have begun to wonder whether the pendulum has not swung too far. They fear that a generation hence might find us in the anomolous position of being able to expound the most intimate details of the physiological processes of infection and resistance without anyone left to tell us what pathogen we are extolling. But taxonomy will always be part of the basic vocabulary of biology; without it we are helpless to communicate with others.

Let me refer to a recent incident that illustrates the experience many mycologists encounter from time to time. Biochemical interest in a culture of a fungus derived from a fruiting body was stimulated when it was found that this culture was a rich source for the production of galactose oxidase. Presumably, the fruiting body from which the culture was derived was sent to a competent mycologist who identified it as Polyporus tomentosus. Publication of the information that P. tomentosus was a source of galactose oxidase resulted in several requests for cultures of this species from our stock culture collection. None of these cultures performed in the prescribed manner. As you have already guessed, examination of the original culture disclosed that it was Dactylium dendroides (Bull.) Fr., parasitic on the specimen of P. tomentosus.

Briefly, let me go back in history to outline the development of plant pathology in Canada. Plant pathology in North America dates back less than 100 years to the era of such pioneers as Farlow, Scribner, Galloway, Bessey, and others. It was an imported science, its knowledge and training borrowed from the European schools of de Bary and Koch. A period of 25 years was required for plant pathology to make its way across the Atlantic Ocean to the United States and another 35 years elapsed before it reached Canada. It was in 1909 that the first plant pathologist, H. T. Güssow, was appointed to the federal Department of Agriculture.

As in Europe, plant pathology in North America found its strength in the able mycologists of this early era. Plant pathology was, in fact, not much more than applied mycology; the taxonomy and biology of the causal fungi leading to control recommendations. In Canada, reference may be made to the contributions of such early mycologists as Buller and Bisby (University of Manitoba), Fraser and Dickson (McGill University), Faull and Jackson (University of Toronto), John Dearness (London, Ontario). Even with such a strong base to build upon, plant pathology in Canada has developed more slowly than in other countries. It is, perhaps, understandable when one considers our small population and limited financial resources in relation to the extensive agricultural and forest areas, the diversity of crops, the variation in soils and climatic regions. We could not very well afford to divert much of our applied research effort to the more fundamental aspects of plant pathology without impairing the research programme concerned with urgent grower problems. It is true that many of our problems are similar to those in the United States and the temperate regions of Europe and that we have borrowed heavily from them. Nevertheless, considering the limitations of our research resources and the heavy demands of the agricultural and forest industries, it is a tribute to such men as Güssow, Craigie, Neatby and Hanna through whose personal research and organizational foresight our programme of applied research in the Research Branch of the Canada Department of Agriculture is supported by basic or fundamental research. In the 50 years since Güssow's appointment as the sole mycologist-pathologist-botanist in the federal department, there has been an expansion of professional staff in pathology and mycology until today the number exceeds 170. Although only a small part of this staff is engaged in basic research I might make special reference to such centres as the virus research group of the Research Station in Vancouver, British Columbia, the group devoted to the study of host-parasite relations in the rusts at the Research Station, Winnipeg, Manitoba, and the Pesticide Research Institute at London, Ontario. So much for credentials.

Rather by force of circumstances than by design we have not forsaken taxonomic mycology in favour of the more glamorous frontiers of biochemical-physiology-phytopathology to the degree that it has happened in certain other countries. To this extent we must admit our backwardness! In the systematic mycology unit of the Plant Research Institute at Ottawa there is a staff of 17 mycologists, at least some of whom are familiar to you. I might mention such names as Groves for his contributions in the Dematiaceae, Sclerotiniaceae, Agaricaceae, and seed-borne fungi; Nobles, who has made a notable contribution to the knowledge of wood-destroying Hymenomycetes; Savile, for his work on the rusts; Hughes, who has caused so much consternation with his proposed revision of nomenclature in the Hyphomycetes; Gordon (Winnipeg), for his contribution to the clarification of the Fusarium complex. That the majority of the most important economic plant disease problems in Canada, as elsewhere, are caused by fungi and are likely to continue so is apparent. That much remains to be learned of the taxonomy and phylogeny of these fungi as well as their cytology, physiology, sexuality, evolution, and habit is equally evident. That we have a substantial number of mycologists to undertake this task is fortuitous but reassuring. That we shall be able to maintain this position is dubious as sources of trained mycologists dry up.

A striking example, based on Canadian experience, of the continuing need for a sound taxonomic framework upon which plant pathological knowledge can be rationally accumulated is to be found in the work of Nobles (1948). Until 1948, relatively few of the wood-inhabiting fungi isolated from decay of forest and ornamental tree species could be identified by cultural characters in the absence of fruiting bodies. It was the painstaking studies over a period of many years of the detailed macroscopic and microscopic characters of cultural isolates from decayed wood and correlation with cultures from identified fruiting structures that enabled Nobles to provide forest pathologists with workable keys for the identification of most of the commonly occurring wood-destroying fungi. The possibility of assessing the importance of these diseases and establishing the distribution, host range, etiology, etc., of these fungi was realized. Without this taxonomic tool we would still be in the darkness of the deep forest. In addition to the applied importance of this taxonomic study, there has emerged a revaluation of possible phlyogenetic relationships in the Polyporaceae (Nobles, 1958).

Consider, for example, the confusion that synonymy of the dwarf bunt fungus has created. For many years dwarf bunt was not recognized as distinct from common bunt. Young (1935) recognized that the two diseases were not the same and considered the dwarf bunt fungus as a variety of Tilletia caries. Holton (1941) distinguished it as a race of T. caries and later Fischer (1952) showed that it was morphologically different from the common bunt fungus and designated the pathogen as a new species, Tilletia brevifaciens. Conners (1954) pointed out that T. brevifaciens was not specifically distinct from T. contraversa described by Kühn in 1875. By this means Conners showed that far from being confronted with a new disease problem, the pathologist had available for the taking a great deal of information on the distribution and host range of the pathogen of a disease of long standing. The hunt was on. Duran and Fischer (1956) re-examined herbarium specimens from many sources and listed some eight synonyms of T. contraversa. Fischer and Duran (1956) have summarized the earliest records of dwarf bunt in North America (and in Europe and Asia) and have shown that it occurred as early as about 1860 in New York State. From a pathological point of view clarification of nomenclature and distribution in this case is particularly significant. The dwarf bunt fungus differs from the common bunt pathogen in one important respect in that the spores may remain dormant in the soil for several years before germinating. Seed treatment, so effective against common bunt which is seed-borne, is not effective against soil-borne spores of dwarf bunt. Recognition of the fact that two distinct pathogens were involved has paved the way for an understanding of biological differences. Similarly, recognition of the distinction between the two species is essential in the breeding for bunt-resistant varieties of winter wheat.

How can the plant pathologist acquire a full appreciation of pathogenesis without the mycological correlation of the imperfect and perfect states and their relative pathogenic importance? Clark and Zillinsky (1960) have recently shown, for example, that ascospores of Leptosphaeria avenaria f. sp. avenaria (imperfect stage, Septoria avenae f. sp. avenae) were the principal source of primary infection, a fact overlooked in the epidemiology of this disease. I am certain that many similar examples immediately occur to you. Without knowledge of the perfect stage, variability in the pathogen through segregation and recombination of genetic factors governing pathogenicity poses an impenetrable barrier to the genetic interpretation of host-parasite relations. How many important pathogens are there in which the connection between perfect and imperfect stages have not yet been established?

Traditionally, the universities have treasured their prorogative in the non-applied or basic areas of research, for it is only in an atmosphere of advanced liberal thought that the responsibility of the teacher can be effectively discharged. It was in this liberal climate that classical mycology flourished and it is here that research and teaching of taxonomic mycology should be safeguarded, free from the vagaries of governmental and industrial pressures. How natural that when phytopathology entered the new era of physiological emphasis the universities should take the lead. But freedom is not synonymous with irresponsibility. Plant pathologists have in the past been endowed at the university with a solid mycological training no matter at what level or direction their future researches were to take. What could be more 'basic' to the study

of the diseased plant than the organism that causes the disease? I do not for one moment suggest that we go back to the position of thirty years ago when our knowledge of the physiology of parasitism was all but non-existent. Neither do I advocate the equally untenable position of arresting mycological research and comitting all our resources to the physiological and biochemical viewpoint. Obviously, what is required is a recognition of the necessity of maintaining a balanced complementary training and research programme.

That mycology will not be entirely neglected in this headlong rush to the new sciences is assured in Canada. There, over 80 percent of the plant pathologists engaged in research are in government employ and the responsibility of governmental agencies lies in the achievement of practical objectives in the solution of disease problems confronting its most important primary industries. These considerations constitute a sobering force that will influence the type of training given at the university.

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HERB. I. M. I. AND THE IDENTIFICATION SERVICE

M. B. Ellis
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One of the two main objectives of the C. M. I. at the time when it started as the Imperial Bureau of Mycology in September 1920 was the naming of fungi injurious to crop plants. Up to the outbreak of the last World War nearly all specimens sent in for identification were plant pathogens; since the war, however, there has been an ever increasing number of requests for moulds of importance in industry and fungi isolated in the search for new antibiotics to be named. Veterinary and medical mycologists ask for our help. This has necessitated several important changes in the set-up of the identification service; it has underlined the importance of maintaining a living culture collection, has drawn attention to a real shortage of reliable monographs dealing with certain groups of fungi and the need for a great deal more taxonomic work to be done. Keys based on host plant-fungus relationships and on the location of fungus fructifications in, on, or emerging from natural substrata are of little value when a fungus is received in a test-tube.

Matching Specimens

In all herbaria great importance is attached to the matching of unnamed specimens against named ones. If the first specimen of a species deposited in your herbarium is incorrectly named it follows that all future specimens matched against it will be wrongly named also. The only way to be at all sure that the first specimen is correctly named is to compare it with either the type collection of the species, or an authenticated specimen. With the permission of the director and through the kindness of Miss E. M. Wakefield O. B. E. and Dr. R. W. G. Dennis many of the first specimens of a species in Herb. I. M. I. have been directly matched against type collections in the Herbarium of the Royal Botanic Gardens, Kew. Curators of other herbaria also have been most helpful in lending us types. The borrowing and returning of specimens is, however, a slow process. To speed up the matching of specimens our mycologists from time to time visit other herbaria. These visits are of the greatest value to the herbarium. Often several hundred specimens can be matched during a single visit.

Storing and Locating Specimens

Named specimens have to be properly looked after, labelled and numbered so that each one can be referred to precisely and stored in such a way that visitors as well as members of staff can find them easily and quickly. Every specimen is carefully catalogued and cross-indexed under fungus and host names and the location of each genus in the herbarium is shown in our genus disposition book. We like to have large representative collections because plant pathologists and others from different parts of the Commonwealth and mycologists from other herbaria visit Herb. I. M. I. from time to time, and when they do they are encouraged to examine specimens. We also like students to work here, but can supply them with material only if this is available in sufficient quantity. To accommodate specimens received at the present rate two new herbarium cabinets are needed each year.

The Mycologists

Although nearly every mycologist at the C. M. I. does some identification work many of them have other duties which occupy much or almost all of their time. Miss Waterhouse, who deals with Phycomycetes other than Mucorales and is an authority on the genus Phytophthora, helps to edit R. A. M., and prepares the Bibliography of Systematic Mycology. Dr. Ainsworth identifies the smut fungi and edits R. A. M. and the Review of Medical and Veterinary Mycology. H. A. Dade has the Mucorales and species of Aspergillus but is also Assistant Director and runs the Culture Collection. F. C. Deighton is chiefly interested in Cercospora and allied genera and in West African fungi; he also checks and edits the Index of Fungi. K. A. Pirozynski deals with general identifications especially of Ascomycetes and also prepares the Distribution Maps of Plant Diseases. Dr. Booth examines Pyrenomycetes and specialises in the Hypocreales and their conidial states including Fusarium. J. J. Elphick has all species of Penicillium, Paecilomyces and Sporotrichum and helps with Aspergillus and the Mucorales and Dr. Davies is interested in slimy-spored Hyphomycetes; between them they cope with many of our culture

fungi. Other groups are covered by B. C. Sutton (Coelomycetes) and G. F. Laundon (Basidiomycetes, especially Uredinales). My own special interest is in the dry-spored Hyphomycetes, including Helminthosporium and its allies. In the year 1921-22, with 3 mycologists on the staff fewer than 200 specimens were examined, in 1938-39 with 6 mycologists the number of specimens rose to 500, in 1958-59 the 11 mycologists named more than 4,000 specimens.

Technical Assistants

Before a fungus can be identified microscopic preparations which demonstrate its structure clearly and precisely must be made. Sometimes a small colony of a fungus scraped from its substratum and mounted on a slide in lacto-phenol cotton blue and warmed after the coverslip has been put on provides a sufficiently good preparation, but often this is not enough. Thin sections may have to be cut with a freezing microtome, fragile colonies removed by the 'necol' technique, single-spore isolations made, or slide cultures prepared. These very useful but time-consuming operations are carried out most efficiently by our technical assistants, who also lay-in all specimens, dry down cultures, disinfect collections, and fumigate cupboards.

Books and reprints

In the herbarium we have an excellent small library of books and reprints dealing with the taxonomy of fungi. We need more accurate descriptions of fungi, fuller accounts of their life-histories and cultural characters, clear photographs and drawings, and a system of classification which will enable us to identify specimens either on natural substrata or in culture. This need is being met gradually and a very fair contribution made by our mycologists who spend much of their own time writing Mycological Papers which are published by the C. M. I. The Dictionary of Fungi compiled by Dr. Ainsworth in collaboration with the late Dr. Bisby should be in every mycological laboratory and herbarium. The fifth and much enlarged edition is now in the press and should be issued before the end of 1960. [It is now available from C. M. I., price 30s. 0d., post free. Ed.]

THE C. M. I. CULTURE COLLECTION

H. A. Dade
Commonwealth Mycological Institute

In our little book, 'Herb. I. M. I.', I have given an account of the general principles of management and the problems of our Culture Collection, and of the methods which we use. I would like now to speak briefly of other matters, to discuss the function and significance of the Culture Collection in relation to the work of the Institute and to research, practice, and education in fungus taxonomy and applied mycology, both in agriculture and industry.

When the C. C. came into existence in 1947, we thought of it as primarily a living extension of the Herbarium collections, and therefore related in the same way as the Herbarium to taxonomic work, but providing living material, for research and comparison, at the disposal of both our own staff and workers elsewhere. This is still, of course, an important part of its functions, but our original conception has broadened a great deal.

I had the inestimable advantage of working with E. W. Mason, whose conceptions of the natural history and taxonomy of fungi informed and inspired all that we did. So from the outset we have always followed Herbarium principles and practice, and you will see this reflected in our Catalogue. The Catalogue, however, is out of step in one respect: we cannot print in it the many unpublished dispositions which will be found in Herbarium folders, and which show that the Herbarium is not only up-to-date, but ahead of time! We have in the Collection a great many more cultures than appear in our Catalogue. In our files these appear as 'reserved', because they have not yet been described and they carry a provisional species number instead of a specific name. These cultures accumulate, in the same way as the corresponding material in the Herbarium, until such time as the groups they represent can be reviewed and described in a Mycological Paper.

We also maintain numbers of strains of particular pathogens which are collected by pathologists who have undertaken comprehensive comparative studies, until such time as they are required. The topical example is Phytophthora palmivora, of which we have many strains deposited by workers in three cacao growing countries.

In less enlightened times mycologists appear to have regarded culture collections as having divine authority. They were sometimes called 'Type Culture Collections', and there was quite a touching belief in their infallibility. The labels on their tubes were accepted with innocent faith. It was a sort of magic which I fear still has power in some quarters. Our own humble outlook is shown by our Catalogue. The names we use in the Catalogue are those approved, at the moment, by our Herbarium pundits, than whom I believe there is no better earthly authority; but theirs is not the word of God, and therefore we print after the names the full details of the origin of each isolate, with the identity numbers attached to it by all who have handled it. It is thus provided with a birth certificate which establishes its unchangeable identity. Those who prefer to use a different name may do so. Without these details the Catalogue would be useless to taxonomists, and to industrialists, too. In industry, special strains, known to possess certain bio-chemical characteristics, are required, and no others, and they can be recognised only if their dossiers are complete. Unfortunately some other collections do not provide this essential information and their catalogues are of very limited use.

Though cultures are useful in taxonomic research, their limitations should be kept in mind. Everyone knows that, in the extremely unnatural and unfavourable conditions of cultivation in vitro, fungi are very likely to deteriorate, losing the power to produce some if not all of their spore forms, while mutation is not uncommon. When the natural habitat strongly resembles that of in vitro conditions, as in the case of common domestic moulds, behaviour in culture is more closely typical, but even in these cases deterioration and change occur. The idea of a 'type culture' is a fallacy, though cultures derived from type material and authenicated cultures have, of course, a special significance.

The real value of a culture in research is that it shows us not merely a mature fructification, but the course of development of that structure, and how the spores are produced; and important features can be seen in living fungi which have disappeared in dried specimens. Keeping in mind the shortcomings of cultures, and watching not with the eye of faith, but with the scaly eye of scepticism, much objective value may be extracted from a culture.

Our great object in life is of course to maintain our cultures in good condition as far as possible and as long as possible. 'Behaviour' includes not only the characteristics of sporulation, but also physiological characteristics. Instability in these affects not only pathogenicity but also the biological features which are of interest to industry. In our experience, it appears that the latter are more easy to maintain, by mass transfer, than the former. In general, pathogens are not easy to maintain in good form in a culture collection.

Our difficulties point the directions of research. I have indicated some of these in our symposium, and I need not repeat them here, except to say that we know very little indeed about what is meant by that glib term 'natural habitat'. Our greatest need, in my opinion, is a great deal more knowledge of micro-ecology. There is here an extensive field for rewarding work. Also, we often wish that we had a biochemist to assist us.

The Culture Collection is a public collection; that means that we have the task of supplying cultures to the public on demand. Although our collection is still a small one (we have nearly 3,000 isolates) we rarely fail to supply what is required. The demands we receive are not by any means confined to fungi of purely taxonomic interest, for we send out large numbers to industry, schools, and technical colleges. Those categories make up the largest part of the 1,800 cultures which we issued last year. I believe that no other institution in this country, or perhaps in the Commonwealth, is so well-equipped for the supply of industrial and educational cultures, simply because of our taxonomic background and of those invaluable working tools, the herbarium collections and the library. Although the Institute has its roots in agriculture, these other aspects of mycology are, I believe, a legitimate part of its activities.

More and more we are consulted by industrial firms and public institutions who have problems created by destructive moulds, and there are many of them. We are asked to identify such fungi, and to suggest means for their control. We advise bodies who lay down specifications for testing mould-proofing procedures, which are applied by a surprisingly large number of firms nowadays. We supply cultures for these tests, and we show works chemists and engineers how to handle them.

We have, too, a collection of special strains used for organic synthesis and for biochemical assay, and there is a steady demand for them. Thus the useful and destructive fungi broadly called 'moulds' have become the special province of the Culture Collection.

I have always made a point of giving help very freely to biology teachers in schools and colleges. They usually know very little about handling fungi and mounting demonstrations. This is natural enough, because mycology is notoriously neglected in university Botany Departments (with one or two notable exceptions). Many teachers are very keen. They do far more than their syllabuses call for, and eagerly and gratefully accept help. For them we have accumulated a very useful collection of isolates, including spectacular things which seize the imagination, and we have devized simple techniques suitable for their limited facilities. I believe it is good policy to stimulate interest in young people at the impressionable age, when a little inspiration may lead to great things. Here again our background and equipment are invaluable - we know what to teach teachers! I hope that some day the Institute may stand in statu parentis to an advanced centre of mycological education here at Kew.

Though I am familiar with one or two groups of fungi and can identify organisms belonging to them, I could not pretend to be a taxonomist. I began my working life as a plant pathologist, extremely interested in practical problems, but in extreme ignorance of taxonomy, and I do not know what I should have done without the I. B. M., then in its early youth, but happily already in possession of Mason. I am now ending my work here as a fungus gardener, with a profound conviction of the importance of taxonomy as the essential background of all mycological activity - all of it, not only plant pathology. Perhaps I should add that taxonomy in this Institute means natural history, too, not mere book work. I cannot imagine a culture collection of any value which lacks a proper conception of taxonomy. I am sure that Dr. van Beverwijk, who is to follow me, will agree, for her Collection at Baarn is the greatest of them all.

Though our collection is steadily becoming more known and useful in the United Kingdom, it seems that the overseas Commonwealth countries are not fully aware of the services which we can give them. Of course, mycologists and pathologists know all about us, but industrialists and teachers do not. I hope that delegates to this Conference will help to spread the news when they go home.

I would also ask delegates, and all mycologists, to send us cultures. We receive their cultures which they send for identification, but we should also like to have common and well known fungi, especially pathogens, which are not sufficiently well represented in our collection.

ARE "TYPE CULTURES" TYPE MATERIAL?

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At the Nomenclature Sessions of the 9th Botanical Congress at Montreal the question of living types was raised. Since no description, however detailed, can ever describe as much as the eye can see, all taxonomists will agree that type cultures or type material should be used to fix the application of names. But can a living organism be of type value? In my opinion this question can have no general answer. If the diagnosis of a species is based on physiological characteristics, as is the case with bacteria and with most yeasts and Actinomycetes, these characteristics can be studied and compared only in cultures, and living types of these organisms are the only possibility.

Let us now direct our attention to the filamentous fungi. For many years plant pathologists and taxonomic mycologists had their hunting grounds in common, both studied fungi from living, diseased, and dead plants which provided excellent natural herbarium material. Although fungus diseases of plants will always remain a field of close contact between phytopathologists and mycologists, the latter recently have been exploring the mould content of at least three of the classical elements and many new species have been and are being described from soil, air, and water. Diagnoses are based on the characteristics of the living organisms in pure culture and, since the original substrates do not provide herbarium material of the fungi, these cultures are being deposited as "type cultures" in type culture collections.

The name, Type Culture Collection, applied to a fungus culture collection, implies that living types are recognized. Is it proper to consider these cultures, originated from type material, as of type value after they have left the jurisdiction of the authors?

In my opinion only the authors' cultures are true type cultures; all transfers from these I would designate as "Cultures from type material". Perhaps we should coin a term for this, such as "culto-type",. but I hesitate to add a new kind of type to the long list of those already existing!

The importance of maintenance of these fungus cultures in reliable culture collections is not questioned since living organisms are, of course, essential in all investigations of their physiological and biochemical properties, including their use in industry for the production of organic acids and antibiotics and for various microbial conversions. From a morphological point of view, also, living cultures are vital in studies of range of variability of a species, in observations of growth responses on different media and under different environmental conditions, and in investigations of the relationship between perfect and imperfect stages of fungi with pleomorphic life cycles.

On the other hand all those who have to deal with fungi know only too well how difficult it sometimes is to maintain cultures in sporulating condition, particularly Ascomycetes, which are reluctant to produce their perfect stages in culture. Time and again "type cultures" sent to the Centraalbureau voor Schimmelcultures lose much of their characteristic morphological appearance on repeated subculturing, in spite of all the pains taken to keep them in typical condition.

Moreover, living cultures are subject to most of the hazards that threaten all living beings: infections by other organisms, general deterioration and death from neglect or accident. Whether a cultured fungus ever dies of old age I do not know, but it seems doubtful, since we have several strains in the C. B. S. collection that have now been maintained for more than 40 years! For all these reasons it seems to me rather risky to base the type of a fungus on only a living culture.

In order that investigators of both taxonomic and applied mycology may be provided with the fungus material they need for their research, I would suggest that each cultivable new species should be handled according to the following system:

1) In order to preserve the biochemical properties as far as possible, each culture should be maintained in at least 3 different ways: actively growing on culture media, under mineral oil, and in the lyophilized condition. All of these preparations could be labelled "from the type" but not "type".

2) For the preservation of the morphological characters, dried cultures and slide mounts from which the diagnoses were made, should be sent to the large herbaria. This material would be designated as "type" and its location should be included in the original description.

Dr. Bisby in his "Taxonomy and Nomenclature of Fungi" in the chapter on "Types and the Type Method" has already suggested that "a culture does not necessarily solve a taxonomic problem" and that "a culture dried soon after isolation, or at least while still sporulating, has a more permanent value for taxonomy".

There remain, then, two questions: 1) what is the best method of drying and 2) should the dried cultures be prepared by the author or should they be processed into

herbarium material at the culture collection to which he sends his culture for maintenance?

The method of drying will depend on the fungus. Some fungi, especially those that develop fruiting structures slowly, can best be cultivated on slanted agar in tubes. A piece of sterilized lupine stem coated with a favourable culture medium, may make a good substrate for growth and drying afterwards. Fungi that develop well in Petri-dishes can be dried as such. After many years of experimenting at the Commonwealth Mycological Institute a method for drying Petri-dish cultures has been worked out. Since Dr. Wiltshire first published on this method in the TRANS. BRIT. MYCOL. SOC. in 1930 this technique has been improved by the addition of a cardboard ring frame which prevents curling of the agar film, and a lid which protects the surface of the colony. I am glad that a description of this very practical method has now been published (Herb. I. M. I. Handbook, 1960), for the benefit of all those who want to dry Petri-dish cultures.

There are two sides to the problem of who should prepare the dried culture. For filing in the herbarium and sending out this material on request a certain uniformity in preservation would be desirable and would probably be achieved most easily if the herbarium specimens were prepared at the culture collection. However, in this case the culture to be dried has to be transferred to culture media prepared at that culture collection, which may be slightly different from those used by the author. In the case of fungi that are very sensitive this might result in a slight deviation in colour or growth habit from that described in the diagnosis. In addition the question of the type value of a culture, one transfer removed from the author's would arise.

The ideal solution might be for the author of a new species to send three tubes of this type culture to the collection of his choice: one to be used for transfer and and addition to the collection, one for covering with mineral oil; and one to be used directly for lyophilization. If the collection has adopted a standardized method of preparation of herbarium specimens, the necessary folder or container would be supplied to the author of the species with detailed directions for its use.

I realize that I may have raised more problems than I have solved, but I feel that they need our consideration.

THE IDENTIFICATION OF PLANT PATHOGENIC BACTERIA

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Commonwealth Mycological Institute

Introduction

A bacteriological laboratory was set up at C. M. I. during 1959, with the purpose of providing an identification service for Commonwealth plant pathologists, in particular those in tropical territories.

Identification work is limited by the material available, and as specimens are frequently in an advanced state of decay, and cultures a gross mixture, I shall first discuss briefly the dispatch of cultures and specimens.

Dispatch of Cultures and Specimens

One difference between most bacterial plant pathogens and the saprophytes which are borne on plant material of all kinds is rate of growth. Thus on diseased plant material removed from the plant, and in culture, the fast-growing saprophyte has the selective advantage. Moist, diseased plant material rapidly becomes overgrown with saprophytic bacteria, albeit in a wholly unpredictable way, so that the pathogen may be overwhelmed. However, dry material wrapped in cellophane rather than polythene is usually adequate for the purpose of isolating the pathogen provided that the specimen is sent by air as soon after collection as possible. The examination

of dried herbarium specimens collected months or years previously does not usually result in isolation of the pathogen. Dried herbarium specimens of long standing finish up with the characteristic bacterial flora of dust and air.

Similarly, mixed cultures on nutritionally rich media are usually overgrown with the faster growing saprophytes so that although the pathogen may be present, routine methods of separation will result only in the isolation of the numerically more numerous saprophyte. Selective media of the type used to isolate enteric pathogens from faecal polluted materials would be useful, but little work has been done on selective media in plant bacteriology. Thus the burden is heavily on the plant pathologist to collect fresh material and send pure cultures. 3" × $^3/_{16}$" test tubes containing a half inch plug of agar medium are most suitable for dispatch of single colony isolates, and are also more economical for dispatch by air than larger test tubes.

Screening of Mixed Cultures

Mixed cultures on agar plates are examined under the dissecting microscope and all colony forms differing in morphology or pigmentation are sub-cultured. Pure cultures of the different colony types are stained by Gram's method and inoculated into the medium of Hugh and Leifson (1953), in order to determine the type of metabolism of carbohydrates. This simple and elegant method divides bacteria into two major groups, the faculatative anaerobes with a fermentative metabolism of carbohydrates, and the aerobes with an oxidative metabolism of carbohydrates. The fermentative group includes all the Erwinias, with the exception of the fireblight pathogen, E. amylovora, which gives an anomolous reaction, and the pectobacteria or soft rot bacteria, which in addition to being fermentative are also potent gas-producers. The oxidative group includes all the xanthomonads, except Xanthomas uredovorus and X. stewartii, all the pseudomonads, and the genus Agrobacterium, with the exception of A. gypsophilae, which has been incorrectly classified.

Systematic Examination of Pure Cultures

The criteria used in the identification of plant pathogenic bacteria can be grouped under various headings such as morphology and staining reactions, biochemical reactions, nutritional requirements, temperature relations, tolerance of inhibitors, serology and phage-typing. Specially developed media are required for the demonstration of pigmentation in bacteria; for example, the brown diffusible melanin-type pigment characteristic of most strains of Pseudomonas solanacearum (Hayward, unpublished) and the green, diffusible, fluorescent pigment of Pseudomonas syringae (Paton, 1959).

Most of the bacterial plant pathogens are straight rod forms, with very little gross variation in size and shape. Morphological differences are subtle and not easily defined. However, there are some differences in staining reactions, apart from the classical Gram stain, which recent work has brought to light (Hayward, 1960). The tropical pathogen, Pseudomonas solanacearum, has the striking property of forming, when the cells are grown on an agar medium containing a readily utilizable carbohydrate, massive inclusions of a storage substance which has a strong affinity for the fat strain, Sudan Black B. This characteristic is shared by the carnation wilt bacterium, Pseudomonas caryophylli, and relatively few other plant pathogenic bacteria.

Most bacterial plant pathogens form capsules which are not usually discrete structures with a clearly defined boundary, but consist of a loose slime or mucus particularly evident on media containing a high concentration of carbohydrate, and the colony characters are affected accordingly. Levan production by pseudomonads on 5% sucrose nutrient agar is a valuable criterion.

Bacteria are either motile of non-motile; the plant pathogens with few exceptions are actively motile. Although motility of bacteria is easily observed in hanging drop preparations, observation of the distribution of flagella about the bacterial cell required considerable practice, if reliance is to be placed on any one of the several staining techniques that are available. Mode of flagellation of bacteria is of critical importance in identification, as exemplified by Leifson (1959).

Biochemical methods are widely used in the identification of bacteria; they

include qualitative tests for enzyme activity such as starch hydrolysis, lipase, urease, β-glycosidases, proteolysis, pectate gel liquefaction, and tests for the utilisation of particular sources of carbon such as citrate, malonate, and gluconate.

Some plant pathogens have specific amino acid or growth factor requirements, as shown by Starr (1946). For example, Xanthomonas albilineans, the sugarcane pathogen, and some other xanthomonads, require the amino acid methionine for growth in an otherwise complete chemically defined medium. Such criteria as this are valuable tools in identification work.

Determination of the minimum, maximum, and optimum growth temperatures shows some important differences among the plant pathogenic bacteria. The corynebacteria have a low optimum temperature, notably the lucerne wilt organism, Corynebacterium insidiosum, with an optimum between 12 and 21°C. In several well known text books it is stated the Pseudomonas solanacearum has an optimum temperature of 37°C., but many authentic cultures recently examined have failed to grow at all at this temperature (Hayward, unpublished); 27-30°C. is a satisfactory incubation temperature for plant pathogens, with the exception of the corynebacteria.

Serological methods and bacteriophage sensitivity testing can sometimes be used to distinguish between bacteria which are indistinguishable on morphological and physiological grounds. Bacteriophage sensitivity testing is complicated by the fact that bacteriophages differ widely in their host range: they may be capable of attacking a wide range of species within a genus, or they may be restricted to a single strain. Several laboratories are now engaged in the use of bacteriophage in the identification of plant pathogenic bacteria and in taxonomic work (Billing, 1960).

Plant Inoculation in Identification

It is rarely possible to identify a plant pathogen with complete certainty without carrying out inoculations into the original host. In the genus Xanthomonas, for example, species determination is on the basis of host specificity, and correlated physiological characteristics still remain to be discovered to obviate the necessity for carrying out plant inoculations. Although xanthomonads have a number of characteristics which distinguish them as a group from other yellow bacteria on plant material, the plant pathogenic, green fluorescent pseudomonads can only be distinguished with difficulty or not at all from other pseudomonads on plant material.

Although plant inoculation is essential for accurate identification work at present there is little doubt that the carefully controlled side by side comparison of plant pathogens using the newer techniques will eliminate, in some cases, the necessity for carrying out plant inoculations.

In this talk I have stressed techniques, that is to say the means by which bacteria can be identified and described. Until bacteria are fully described there cannot be a satisfactory taxonomy, and most workers would agree that descriptions of many bacterial plant pathogens in the literature are quite inadequate for identification purposes. It is unfortunately easier to create a new species when a bacterium is isolated from a new host than it is to demonstrate a relationship with existing species.

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THE FUNCTIONS OF A CULTURE COLLECTION OF PLANT PATHOGENIC BACTERIA AND BACTERIOPHAGES
(Summary)

R. A. Lelliott
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Ideally a collection such as the National Collection of Plant Pathogenic Bacteria should maintain for the use of plant pathologists and bacteriologists authentic cultures of proved pathogencity of all the described species of bacterial plant pathogens; enough isolates of each species, representative of host range and geographical distribution, should be maintained to provide material for studying all aspects of this group of pathogens and particularly for work in taxonomy and pathology.

A supply of specific bacteriophage cultures and specific antisera for diagnostic work would be a useful service for such a collection to provide but it should not be regarded as one of its main functions.

Lyophilization is considered to be the only practical way of adequately preserving cultures in a collection and the 'freeze-drying' method used at Harpenden is described.

The degree to which the National Collection at Harpenden has achieved these aims is assessed.

Discussion following papers by A. J. Skolko and M. B. Ellis

A. J. CARR (U. K.), while appreciating the value of taxonomy to plant pathology, thought that it had declined in relation to other disciplines largely through its failure to take into account information derived from them, e. g. from cyto-taxonomy and biochemistry. Hence although El Ani had shown Hypomyces solani and H. solani f. cucurbitae to have quite different chromosome numbers, and therefore probably to be sexually isolated, classical taxonomists would reject the raising of f. cucurbitae to specific rank on the grounds that classification must ba based on morphology alone. A more realistic approach would be to take into account relevant information from all disciplines; taxonomy could then play its full role in the solution of phytopathological problems.

C. BOOTH (U. K.) said that mycologists at C. M. I. did not consider that El Ani was working with genuine Hypomyces solani Reinke & Berthold. Nevertheless, he (Booth) personally believed that H. solani and H. solani f. cucurbitae were distinct species.

C. L. A. LEAKEY (U. K.) agreed that there was frequently a lack of contact between classical and modern or experimental taxonomists, but had been impressed by how closely in contact with these problems the C. M. I. is.

J. B. LEBEAU (Canada) stressed the necessity for biochemists and physiologists to undertake research in collaboration with biologists. Alone, they often take insufficient account of randomisation; chemists, for example, often taking inadquate samples.

Discussion following papers by H. A. Dade and A. L. van Beverwijk

J. C. F. HOPKINS (U. K.) pointed out that when dried cultures are indicated as types

the question of culture media had to be considered. The best solution would probably be to devise series of standard media to accommodate different groups of species; the substratum must then be stated when describing the type.

MISS A. L. VAN BEVERWIJK (Netherlands) said that a culture must be grown on its optimum medium. At Baarn they often kept dried cultures of a species on two different media, e. g. one for the perfect and one for the imperfect state.

Discussion following papers by A. C. Hayward and R. A. Lelliott

J. C. F. HOPKINS (U. K.) drew attention to the fact that freeze-drying of bacteria would be demonstrated at Harpenden when the Conference visited the new Ministry laboratories.

MISS M. NOBLE (U. K.) said that they had experimented with the freeze-drying of Phomas and other seed-borne fungi at East Craigs, since they felt they could not ask a culture collection to keep them for them. They had found the technique to be very critical and slight changes in medium could effect successful preservation.

H. A. DADE (U. K.) doubted the need for freeze-drying in many cases, as the majority of fungi could be kept quite successfully under oil.

MISS A. L. VAN BEVERWIJK (Netherlands) said that at Baarn they had found freeze-drying to be very successful for Aspergillus and Penicillium. The tubes are checked immediately after processing and if they are viable then they should survive for many years.

MISS M. NOBLE added that they started to freeze-dry cultures at East Craigs because of very limited space, but at present they are kept as ordinary slope cultures as well.

July 18 morning

Root Diseases

Chairman: Dr. J. B. Lebeau

ARMILLARIA MELLEA IN KENYA TEA PLANTATIONS

I. A. S. Gibson & N. A. Goodchild
E. A. A. F. R. O., Muguga, and Tea Research Institute, Kericho

Summary

The following hypotheses have been tested with regard to Armillaria root disease, as it occurs on Kericho Tea Estates, during the last three years:

1. That Armillaria mellea was being spread by airborne spores which infected healthy tea plants, either directly or indirectly.

2. That highly pathogenic strains of A. mellea were to be found in the Kericho district.

3. That Leach's ringbarking method to reduce the colonisation of roots in the soil by A. mellea was not proving effective and was perhaps working to favour the fungus in this respect.

A search for sporophores of the fungus on tea estates and in Kenya forest areas has shown these to be extremely rare. Further, no invasion by the fungus was observed to follow the inoculation of freshly cut unsterilised pine sapwood

by suspensions of viable basidiospores of A. mellea. It was concluded from this that spread of Armillaria root disease by air-borne spores was extremely unlikely.

Inoculation experiments on tea to compare the pathogenicity of various Kenya strains of A. mellea showed that the fungus causing disease at Kericho was in no way more pathogenic than those occurring elsewhere.

Examination of the method of ringbarking practiced at Kericho showed that in many cases this had been carried out clumsily, resulting in the death of the tree before exhaustion of root starch was complete. Careful ringbarking has been shown to cause sufficient exhaustion of root starch in Grevillea robusta shade to make colonisation of the dead tree by A. mellea unlikely; some arboricidal treatments have given similar results. Forest trees bearing natural root associations with A. mellea were found to be readily invaded by the fungus on clear-felling but this did not take place when they were killed by ring-barking. While this evidence is not conclusive, it indicates strongly that ring-barking, properly applied, will act to restrict the colonisation of roots of shade and forest trees.

In the course of these investigations it became clear that harmless root associations between A. mellea and indigenous forest trees were extremely common. A further search revealed that G. robusta shade and tea itself frequently carried associations with the fungus. In view of this it seemed very likely that reported outbreaks in older tea fields and those associated with the removal of shade might be due to the disturbance of this balanced state.

It is felt that the possibility of attacks of Armillaria root disease arising from harmless root associations with the fungus has not been sufficiently appreciated until now. However, this does not pose any new problems of control, which can probably be met by clean clearing of plantation sites and maintenance of a high level of crop vigour.

RECENT PROGRESS IN THE CONTROL OF THE WHITE ROOT DISEASE OF HEVEA RUBBER

A. Riggenbach
Rubber Research Institute, Ceylon

Summary

The white root disease of the rubber tree, Hevea brasiliensis, caused by the fungus Fomes lignosus (Klot) Heim, or Leptoporus lignosus (Klot) Heim ex Pat. is of considerable economic importance to the rubber industry of Ceylon. The incidence of this disease is particularly high in 2- to 4- year old plantings.

As the method of control in general use of plantations, consisting of the surface application to infected roots of a 2 per cent. solution of copper sulphate, gave disappointing results an investigation was undertaken to find a more effective fungicide than copper sulphate.

A series of laboratory tests were carried out at the Rubber Research Institute of Ceylon with a wide range of different fungicides, namely, sulphur-based, copper-based, mercury-based, carbamate-based, and various proprietary fungicides, which showed tillex, an organo-mercury fungicide, to be the most effective of all.

Field experiments have confirmed these laboratory findings and also showed that tillex has no phytotoxic effect on the treated plants.

As a result of these experiments and of the successful use of this fungicide for the control of the white root disease in commercial areas replanted with rubber, tillex is now recommended by the Institute, in place of copper sulphate, for that purpose.

The percentage of success obtained with tillex is, on an average, about 80 per cent. when treatment is applied at the first signs of the disease.

[The full paper has appeared in Proc. Nat. Rubb. Res. Conf., Kuala Lumpur, 1960]

WHITE ROOT DISEASE OF HEVEA BRASILIENSIS: RECENT DEVELOPMENTS IN CONTROL TECHNIQUES

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The three major root diseases of Hevea in Malaya are caused by the fungi Fomes lignosus (Klotzsch) Bres., Fomes noxius Corner, and Ganoderma pseudoferreum (Wakef.) van Over. et Steinm. Together they cause a greater loss of crop than all other pests and diseases combined, and of them F. lignosus, locally known as white root disease, is by far the most serious. It is essentially a disease of moist conditions, causing greater loss on coastal and alluvial soils, in ravines, and on undulating land than on hilly areas. It takes its heaviest toll in the early years of a planting but may persist throughout the life of a stand.

Losses caused by F. lignosus can reach a very high level if the disease is not controlled when it first appears. For example, a replanting in 1940 on a coastal estate at a density of 145 trees per acre, neglected during the war, had, by 1956, been reduced to 94 trees per acre. Examination of a three acre sample plot showed that of the 94 trees remaining, 19 trees per acre were infected, of which 7 were beyond treatment. In only 16 years, nearly half the original stand had become infected and over one third of it lost. Attempts at tree treatment and control of the disease at this late stage proved so costly that the Board of the Company ruled them out as uneconomic. As the useful tapping life of modern high yielding rubber is likely to be from thirty to forty years, the seriousness of losses of the order quoted needs no emphasis.

The history of white root disease of rubber falls conveniently into four periods, the first starting with its discovery in 1904 and continuing until 1930. The second period, dominated by the influence of Napper, covers the years 1930 to 1946. The way the situation then stood is well expressed in a comment by Altson (1950b) - "As a result of Napper's work, we now have a fair idea of the cost of root disease control; but we know little of the influence of these measures on yield, and, through yield, on revenue." The third period, from 1946 until 1957, represents a period of transition during which Napper's scheme was found to be open to question. The last period is concerned with investigations still current. A convenient reference to the first period is in the manual "Diseases and Pests of Rubber the Tree" by Petch (1921).

It was early recognised that the disease originated from jungle stumps, and there was much subsequent controversy as to the relative value of clean clearing, no clearing, or selective stumping. This last system lost its protagonists as the lists of known hosts of F. lignosus was extended. Important to this controversy was the role assigned to wind-borne spores as causes of stump infection. Petch (1921) was quite emphatic and stated that its occurrence on jungle stumps in new clearings could only be explained by spore infection. He also considered that it was unsafe to leave stumps of any kind among rubber. The earlier opinions of Gallagher (1909) and Bancroft (1912 b) were not in agreement with this thesis. Clean clearing was opposed by some on economic grounds and by others who were not persuaded of the dangers of root disease or felt that it was best combated when it showed itself on the rubber.

During this period, root disease centres were usually located only when trees showed obvious symptoms in the foliage. At that stage, as Petch (1921) noted, the first tree to be discovered is usually beyond recovery. He describes treatment of diseased areas as involving the removal of all dead trees, decaying stumps, and timber in the infected patch, its isolation by a deep trench, and the application of lime to the soil. Shortly afterwards Bryce (1929) produced evidence that F. lignosus grew better in alkaline than acid media. Nevertheless, lime was still in use on many estates in Malaya ten years later (Napper 1932a).

Bancroft (1912a) convincingly demonstrated that the mycelium of F. lignosus could neither survive in the soil nor cause an infection if separated from its food base. Petch (1921) recognising the need for a food base, emphasised that the fungus must derive its food from the stump on which it originated until it contacts other dead wood or a living plant which it could attack. It is surprising, the need for a food base having been recognised, that Petch should have advocated liming, and that Napper (1932a) should have made this statement: "Fomes lignosus is able to exist independent of its food supply and the removal of timber from an area infected with the latter fungus must be supplemented by careful digging and exposing of the soil to the sterilising action of the sun".

To run ahead in time whilst pursuing the same point, the evidence of Bancroft (1912a) and the opinions of Petch (1921) were given further support by the publications of de Jong (1933) and Altson (1953c). De Jong found that many of his experimental infections healed of their own accord and that unless his inocula were large the disease died out. He was the first person to state, unequivocally, that F. lignosus should be considered a weak parasite. Altson showed that a volume of at least five cubic inches of infected wood was necessary for assured success in initiating infections on three and six month old nursery seedlings. Despite this, Riggenbach (1957), finding that F. lignosus would grow in cow dung in the laboratory, spoke against the practice, often employed in Ceylon, of dipping stumps in cow dung solution to prevent them drying out during transport from the nursery to the field. He argued that such stumps would be more readily infected than untreated stumps if they came in contact with only "minute pieces of mycelium" left in the soil from the old rubber stand.

To summarise the position in the first period: it was one which recognised that the disease arose from infected stumps and roots; this suggested a policy of clean clearing, though there were arguments against it. The presence of root disease was recognized by the occurrence of dying trees; treatment was aimed not so much at saving infected trees as at clearing up diseased areas by digging out and burning infected timber.

The major change brought about by Napper (1932a, b,) was based on his realising that the rhizomorphic habit of F. lignosus and the other two major parasites, with epiphytic growth extending ahead of penetration, could be used to locate sources of disease before much harm had been done to the young stand. The change which he advised was from eradication after loss, with prevention of further loss, to prevention of infection. To this end he advocated tree-to-tree collar inspection at intervals of four to six months. When a tree was found with rhizomorphs at the collar, the source was traced and eradicated, and the tree treated if it could be saved. The more frequent the rounds of inspection, the higher the ratio of treatable to condemned trees. Treatability was determined, then as now, by the extent of healthy tissue; diseased wood at the collar was excised. Epiphytic fungal growth was rubbed off and the exposed roots treated with a fungicide - 2% copper sulphate - to dispose of residual fragments of mycelium.

Napper thought that pre-existing disease centres in the jungle of a new planting, or the old rubber stand of a replanting, were "fixed" at the time of felling and that little further spread occurred. He did not consider wind-borne spores to be of importance in the infection of stumps, although on one occasion he traced an outbreak of F. noxius on the bush cover, Tephrosia vogelii, to spore colonization of old rubber logs that had been used to support the planting terraces. He nevertheless believed that the more serious root parasites, F. lignosus and G. pseudoferreum, were not likely to invade lying timber in the same way (Reported by Beeley 1938). Outbreaks of root disease that might have been attributed to spore colonization of stumps or timber Napper (1937) explained by postulating the existence of dormant sources of infection. He did not, however, entirely exclude the possibility of spore infection (Napper 1939).

During this period Napper had three other problems with which to contend; first the use of cover plants and their effect on root disease; second, the problem of replanting old rubber areas; third (allied to the second problem) the use of poisoning as a method of lessening the costs of clearing when replanting old rubber. He was able to establish that cover plants would reduce disease incidence as compared with clean weeding (Napper 1932a, 1941), a finding confirmed by Cronshey and Barclay (1940); further that the then popular idea of using sus-

ceptible bush covers as indicators of potential disease sources, whilst workable, was uneconomic. This last finding was because the bushes, with their woody stems and root systems, had to be eradicated as potential sources of infection to the rubber (Napper 1940, Altson 1950a).

Napper (1932a) postulated two reasons for the effect of cover plants in reducing disease incidence. First, that of preferential attack. He considered that the covers presented an enormous amount of food material on which the fungus could feed both as a parasite and a saprophyte and that this availability of an alternative food supply would reduce the chance of attack upon the crop plant. Second, he thought that any ground cover would have a "braking" effect on the movement of the rhizomorphs , introducing into the soil innumerable "foreign" roots sytems which would side-track the rhizomorphs and so reduce their collective vigour. It appears anomalous that such effects should be attributed to plants whose root systems supply food material.

About 1936, various factors, viz. prices, wages, and the rubber restriction scheme, combined to make many old rubber areas uneconomic. At the same time the industry was being made more aware of the benefits of bud-grafting with high yielding clones. Progressive planters started to replant their uneconomic areas. There was little new planting, because the restriction scheme did not allow planting of jungle reserves except for experimental purposes.

Napper must have been aware that many old rubber areas scheduled for replanting were in an uneconomic condition because of the ravages of root diseases. The urgent problem facing him was to investigate methods of disposing of the old rubber trees in a way that would combine economy with the minimum infection of the new trees from the old trees. To this end he initiated, between 1927 and 1941, no less than twelve field experiments, all designed to investigate problems of replanting. They are recorded in successive annual reports of the R. R. I. M. for that period. Most were designed to investigate the effects of different degrees of eradication of the old stand, of different methods of poisoning either trees or stumps (as a means of hastening their decay) and of different cover plants. It appears that Napper suspected that his method of post-planting control was not the most economical possible, as one experiment was designed to compare it with a system based on foliage inspection.

Napper's untimely death in 1942 and the unavoidable neglect of his experiments during the occupation period deprived us of much of their value. Such results as were reliable, together with inferences drawn from them, have been presented by Altson (1950a, b, c). The position in 1946 is briefly summarised below.

The scheme of post-planting control outlined by Napper (1932b, 1938) had been well proven for new plantings and replantings. In replantings, pre-planting eradication of the old stand, or removal of diseased trees, were both well established procedures. Stump poisoning with sodium arsenite had been shown to reduce the incidence of subsequent root disease in the young stand where stumps of the old stand were left in the ground. Poisoning was also shown to be acceptable as a method of disposing of the old trees.

Two factors, both noted by Altson (1950b), lead to a more critical outlook on procedures otherwise accepted as being successful. First, on many estates root disease had made little progress during the war years despite almost total neglect. That this should be so was probably the result of the careful pre-planting eradication that had been carried out before the war; it should not be taken as evidence against the need of post-planting control measures. Second, shortage of labour and increased wage rates made both the accepted schemes of pre-planting eradication and post-planting control either impracticable or economically unattractive. These problems could only be attacked by field experiments. During the third period, therefore, experiments were designed to investigate modifications of previously accepted procedures (including an assessment of their economics and effect on incidence) of tree and stump poisoning, of the role of spores, and the problem of dormancy. References to these experiments are given in Annual Reports of the R. R. I. M. from 1948 onwards, using code letters and numbers which refer respectively to the site and to the year of initiation. That they were all concerned with replanting, as opposed to new planting from jungle, reflects on the urgent need to replace areas of old unselected seedling rubber with modern high yielding clones. The main conclusions arrived at during this period are set out below.

Prior to Planting

(i) Eradication

Eradication of an old stand may be complete or it may be partial; if the latter, it can involve removal of all trees found diseased by collar inspection, or of only those diseased trees that stand on the edges of evident disease patches. Comparisons, cannot, however, be made with similar degrees of eradication practised before the war when eradication was combined with digging over the disease patch to remove all buried timber, which was then burnt. Such a course nowadays being uneconomic, eradication is limited to removing a diseased tree and grubbing out its roots.

Experiment CI-51, which was designed to compare three degrees of eradication gave results so anomalous that no conclusions may be drawn from them. Experiment SR-57, of similar design to CI-51, is not completed. We are therefore not yet in a position to give an answer to this problem.

(ii) Poisoning

Napper (1939), discussing the effect of stump poisoning in reducing subsequent disease incidence on the young stand as compared with no poisoning, concluded that the beneficial effect was obtained by hastening the death of the roots, which were then rapidly invaded by saprophytes and thus denied to the parasites. Altson (1950d, 1953a, b) investigated the distribution of arsenic in the root system, and the tolerance of the three major root pathogens to this poison. The experimental findings confirmed Napper's hypothesis. Altson (1953b) was able to state that the concentration of arsenic in the roots was never likely to reach a level that would be inhibitory to F. lignosus or G. pseudoferruem, though it might reach levels inhibitory to F. noxius.

Stump poisoning has been found to reduce subsequent disease incidence in the young stand by 40% to 60% while tree poisoning has given reductions of up to 80%. Ring-barking and applying the poison in a paste to the exposed wood - a cheap and rapid method - is as satisfactory as the more expensive, older methods in which a greater quantity of poison was applied in solution, poured into auger holes.

The reason for the superiority of tree poisoning when compared with stump poisoning has not been established though certain factors are known to operate. The cut surfaces of the stumps may be colonised by wind-borne spores. In addition, if the timber is left on the ground it may also be colonised by spores when newly felled, and it may also be invaded by rhizomorphs from infected roots lying below it, at or near the soil surface. Such colonised timber may then further spread the disease to other pieces of timber or to healthy stumps with which it is in contact. Evidence for these statements is derived mostly from field observations. Later on, results from experiment SR-57 and J-57 may provide experimental confirmation.

(iii) Stump protection

Experiments G-50 and CI-51 indicated that a small reduction in root disease indidence might result from protecting the cut surface of unpoisoned stumps with a proprietary wood preservative, though this treatment was much less effective than stump poisoning. Two further experiments were initiated in 1956 - one on our Experiment Station and the other, super-imposed on CI-56, on Carey Island. Creosote was used instead of solignum, being cheaper, and was applied to stumps which had been poisoned. In both experiments, this treatment has approximately halved the number of stumps that have become sources of infection to the young stand. As the labour charge for removing or isolating sources of infection is the largest item in post-planting control, the additional surface treatment of stumps, which is simple and cheap, represents a most worthwhile precaution. We accordingly advise routine treatment of any stump of a tree that is cut out; as in thinning, or as occasioned by lightning strike, wind damage or brown bast.

Post Planting

The most important results bearing on post-planting control procedures derive from experiment CI-51. Three systems, designated by colours, were compared; green, the 'classical' treatment advocated by Napper, with six-monthly rounds of

inspection; red, recognition of disease by six-monthly rounds of foliage inspection, with subsequent treatment and eradication as in the green plots; yellow, dead trees counted at the six-monthly rounds of inspection, but no treatment given. These systems were used because Altson (1950d) considered it necessary to compare the efficacy of collar inspection with foliage inspection and to put to test a theory, that had gained currency since the war, that the disturbance of the soil which inevitably accompanies root disease treatment actually tends to increase the rate of spread of the parasite. CI-51 was the second experiment of this kind, the first being P-48, which regrettably had to be abadndoned in 1952. Before it was closed down, four rounds of inspection and treatment had been done and the final figures showed that the yellow plots had sustained 15% less losses than the green plots; and that 25% less stumps had been found as sources of infection. It had been anticipated that the initial rate of loss would be highest in the green plots, lowest in the yellow plots, but that in time both the red and yellow plots would have greater losses. It was also anticipated that the proportion of treatable to condemned trees would be higher in the green plots, where the disease was sought for at the collar, than in the red plots. In the yellows plots, of course, it had to be zero.

In CI-51, by mid 1957, the ratio of cumulative losses for green: red: yellow were 2.7:2.5:1.0. The yellow plots were then given a collar examination to determine the total incidence of disease in them. Most surprisingly, the cumulatvie incidence ratios were found to be 2.0:1.5:1.0. Further, at the last inspection of P.48, trees found infected were classified as to their treatability; hence it was possible to derive figures for potential losses, the ratios of which were 1.5:1.5:1.0. It was quite clear that Napper's system, whilst eventually controlling root disease, increased its incidence.

The effect of increased thoroughness of control measures (and its accompanying increased soil disturbance) resulting in increased activity of the disease, has been convincingly demonstrated in another manner. In experiment G-50, each treatment plot was divided for the purposes of post-planting control into two; on one half Napper's scheme was employed, but on the other half stumps found as sources of infection were not dug out but only isolated. The numbers of infective stumps were equal within 2% in both systems; but the incidence of disease on the young stand was in the ratio of 1.3:1.0, and losses in the ratio 1.4:1.0.

The conclusion to be drawn from these results is that the more the soil is disturbed, the more active the disease becomes; yet the disease must be prevented from becoming established and self-propagating on the young stand. The need is to establish the minimum treatment which we think may be achieved by foliage inspection accompanied by isolation of the sources of infection. Tapping the young trees commences when they are somewhere between five and seven years of age; selective thinning, using girth and yield, respectively, as the criteria for budded trees and clonal seedlings, is usually completed by the ninth year. It is obviously important that disease incidence should be reduced to a low level before thinning is started; otherwise trees selected for the final stand may be lost. G. pseudoferreum and F. noxius spread much more slowly than F. lignosus and foliage inspection will not reveal all their centres of infection in the early years. Moreover, the bigger the tree, the longer it will be after infection commences before foliage symptoms are apparent. We, therefore, advise that one or two rounds of collar inspection should be done about the third to the fifth year as a precaution.

The notion that soil disturbance increases disease incidence may be regarded as somewhat anomalous considering that the disturbed soil is supposedly left free from infection. However, if diseased roots are overlooked there are two factors that may explain the experimental results. First, roots inevitably are wounded during digging; contrary to the opinions expressed by earlier investigators we have found that such roots are more susceptible to infection than those with intact bark. Second, epiphytic growth of the fungus can be expected to be more rapid in uncompacted soil. We have observed rhizomorphs growing freely for several inches through lossened soil. In one instance under these conditions, marker posts made from cut rubber branches were colonised. Further, when soil samples were obtained from plots before digging and at weekly intervals afterwards, the growth rate of F. lignosus through them, after they had been air-dried, mechanically sieved, and brought to standard moisture-holding capacity, showed increases up to 20% and some effect was still evident after sixteen weeks.

For two further factors that will affect losses of the young stand and the cost of control measures we have coined the terms "despair factor" and "fear factor". Despite the damage that it may do if left uncontrolled, F. lignosus in its relation to Hevea is essentially a weak parasite. Not only are large inocula required to initiate infections, but really massive inocula are required to produce lesions sufficiently large to be self-propagating. From the work of de Jong (1933) and from our own observations we know that quite large lesions may heal of their own accord. The "despair factor" arises during collar inspection when treatment is given to a tree that would have recovered if left untreated, or when a tree that could have been saved is removed; or, again, when removing a source of infection which no longer has enough inoculum potential to establish the disease on the young tree.

This last leads to the "fear factor": Petch (1921) considered all stumps to be of probable danger. Some managers planted and still plant 'indicator' bushes, supposing all infected roots to be potentially dangerous. Young (1952, 1955a, 1955b) recommended in addition to Napper's standard method of post-planting control that disease patches, after digging, should be thickly planted with an indicator bush to detect the existence of infected wood that had been overlooked. Napper considered every infected stump or root to be of probable danger and sought for them at an early stage. Altson (1950d) thought that every healthy stump was a potential source of infection while infected stumps were seen as actual sources. Now we regard all stumps as no more than potential sources of infection, not all that carry the disease being capable of establishing it on the young trees. This change in view weighs heavily in the economic balance.

One point that remains to be discussed is the role of covers in reducing disease incidence. It is convenient to quote a restatement (Anon 1954) of Napper's viewpoint on this subject: "... the rhizomorphs ... dissipate their reserves in spreading over the dense tangle of cover crop roots". By changing this to read "Dissipate their reserves by infecting" we get closer to the truth. A large piece of infected wood, potentially dangerous to rubber, may exhaust its inoculum potential by infecting a large number of small roots of cover plants. Not only will the disease die out of the smaller roots more rapidly than it would have died out of the large piece of wood, but the roots also have too small an inoculum potential to establish infection in the rubber trees. This assertion needs to be qualified. A given inoculum potential will produce on its host a lesion the size of which will vary according to the host reaction, but it is clear that the effectiveness of the lesion depends not only on its own size but on the size of the host.

Altson (1950d, 1953c, 1954) thought that cover plants might modify the soil microflora in favour of organisms antagonistic to the root parasites. He pursued this idea in small scale field experiments and in the laboratory. These investigations, further reported by Newsam (1958), show that the concept of antagonism was restricted to effects of antibiotic production. Using a buried slide technique, we have observed that the rhizomorphs are readily attacked by species of Streptomyces and Micromonospora, their attack causing dissolution of the hyphal cross walls. The extent of this parasitism has not been made the subject of quantitative experiments, but subjectively the intensity of attack appears to be greatest under covers (where the soil organic matter content is high) and least under bare soil.

The remaining function of covers is probably of most importance. A good creeping cover maintains high humidity, conserves soil moisture and protects the soil from insolation. Under these conditions decay of timber caused by fungi is many times more rapid than with clean weeding. Not only will uninfected wood rot off more rapidly but the succession in infected wood from parasite to saprophytes will also be hastened. Activity of the micro- and semi-micro fauna that attack wood is also greater under these conditions. Cover plants can, however, be a danger if allowed to grow over the planting rows and around the bases of the trees, creating a humid environment just above the ground level. Should the fungus reach the collar, by travelling along a lateral root or on the runners of the cover plants, it is not hindered mechanically by the soil nor biotically by the soil flora; under these conditions it quickly encircles the base of the tree, killing the bark.

Current Investigations

Many field experiments have been initiated in the last four years, and more are projected for 1960. One object is to develop the use of 2, 4, 5-T as a tree and stump poison, as an alternative to sodium arsenite, which is largely denied to smallholders by restrictions on its use, and it is likely to be the subject of further restrictions. Other experiments are designed to investigate the effect of different degrees of pre-planting eradication and mechanical clearing in replanting, and the effect of poisoning in jungle clearings. The role of wind-borne spores is the subject of further studies which include investigations of the site of colonization, the size of the stump, and a search for cheap substitutes for creosote.

Acknowledgements

The recent changes that have been made in control techniques follow from the co-operative work of my colleagues in the Pathological Division R.R.I.M.; Dr. A. Newsam, Head of Division, Messrs. F. W. Hutchison, R. N. Hilton, K. P. John, and B. Sripathi Rao. Mention should also be made of Mr. R. A. Altson, Head of Division from 1946 to 1952 who did so much to salvage and evaluate the results of the many experiments initiated by R. P. N. Napper in the period 1937-1941.

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THE INTERACTION OF Fusarium oxysporum f. vasinfectum AND Meloidogyne SPP: ON COTTON

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Introduction

Root knot and Fusarium wilt on cotton were first described by Atkinson (1892) and he also noted an association between them, asserting that in the presence of

eelworm attack, wilt was more severe. More recently, since the development of chemicals for the control of nematodes in the field, many workers have reported that eradication of root-knot eelworm from the soil resulted in a lower incidence of wilt (Smith, 1948). These chemicals are claimed to have little or no fungicidal activity. Martin et al. (1956) inoculated cotton plants grown in pots with the fungus alone, the nematode alone, and with both together and showed that the incidence of wilted plants was as much as ten times greater in the presence of the nematode than when the fungus was inoculated alone.

Very little critical work has been directed towards an elucidation of the underlying mechanism. Atkinson (1892) suggested that the nematodes damaged the roots and thus provided a more ready means of entry for the fungus. This idea was reiterated by Smith (1954) who also stated that the wilt pathogen is dependent on nematodes for entrance to the vascular system of the plant. These statements, however, are based principally on field observations and there is no direct evidence to support them.

This paper describes some preliminary experiments on the relationship between root knot and wilt of cotton in East Africa.

Fusarium Wilt and Root-knot Eelworm of Cotton in East Africa

Fusarium wilt of cotton, caused by Fusarium oxysporum f. vasinfectum (Atk.) Snyder & Hansen, occurs both in Uganda and in Tanganyika. In Uganda, the disease appears to be restricted to a small area of sandy soils in the Eastern Province of the country and with the introduction of a more resistant cotton variety it is not considered to constitute any immediate danger to the cotton crop. The disease is more serious in the Lake Province of Tanganyika where it has become established on the very sandy soils near to the shores of Lake Victoria. Recent surveys of cotton plots in this region have indicated that the disease is spreading.

Cotton root knot, caused by eelworms of the genus Meloidogyne, principally M. incognita (Kofoid & White) Chitwood, has also been found in both countries. In Uganda, a survey of cotton wilt revealed that the disease was always associated with root knot (Wickens & Logan, 1960), and in Tanganyika the two diseases are frequently found together.

Inoculation experiments done at the Cotton Research Station, Namulonge, showed that a synergistic relationship existed between the local strains of F. oxysporum and M. incognita; 90 days after inoculation wilt symptoms were seen on 50% of the plants inoculated with F. oxysporum and on 96% of those inoculated with F. oxysporum plus root-knot eelworm. These results were confirmed in the field by using a nematicidal chemical on land that was known to be infested with both organisms. Root-knot attack was assessed on an arbitrary scale and the intensity expressed as a percentage of the maximum possible on the scale. Soil fumigation reduced the root-knot intensity from 64% to 15% and this was correlated with a decrease in wilt incidence from 14% to 2%.

It was observed that severe outbreaks of wilt occurred in the very sandy soils of the Lake Province of Tanganyika where there was no evidence of root-knot eelworm attack or damage to the roots by any other form of nematodes. Furthermore, plants developed Fusarium wilt when they were grown in unsterile, artificially inoculated soil and uninjured either by nematodes or mechanically. Clearly, the infection of the cotton plant by F. oxysporum is not entirely dependent on nematodes or other damage.

Sections of cotton seedling roots that had been inoculated with both larvae of M. incognita and spores of F. oxysporum were examined microscopically. The larvae entered the root within 24 hours, and 96 hours after inoculation they were well established in the root cortex. Movement in the cortex was principally intercellular and very little damage to the host tissues was observed. Fungal hyphae were never seen at the points of entry of the nematodes. The fungus was slow to enter the root and 96 hours after inoculation only very few hyphae were seen in the

epidermal and outer cortical cells. The activity of the fungus in the presence of nematodes was essentially similar to that on roots inoculated with the fungus alone. Thus in the early stages of infection, damage caused to the root by the entry of the nematode does not favour penetration by the fungus.

To obtain large populations of the root-knot nematode for inoculation to cotton, tomatoes were grown in soil taken from an area where cotton was severely attacked by root knot. Tomatoes were grown rather than cotton to avoid the possibility of contaminating the root-knot inoculum with F. oxysporum f. vasinfectum. It was found that after three generations of tomatoes had been grown in this soil, inocula containing large numbers of larvae obtained from the tomato roots did not produce many knots on the roots of cotton. It seemed probable that a biotype of the eelworm that was non-pathogenic to cotton had been selected on the tomato. When these larvae were inoculated together with F. oxysporum to the roots of cotton seedlings that were transplanted in soil, the number of plants that wilted was less than when the fungus was inoculated alone. Microscopic examination of cotton roots inoculated with these larvae showed that many larvae were present in the root cortex but that extensive necrosis of the host tissues had occurred. Riggs & Winstead (1959) found that root-knot larvae in tomato caused very little damage to the host tissues of susceptible varieties in the early stage of attack, whereas in resistant varieties, extensive necrosis occurred that prevented further development of the nematode. It is considered that the necrosis observed in the cortical tissues of cotton root was a reaction of a plant resistant to attack by nematodes. Although the damage caused to the roots by this tomato-specific biotype was greater than that caused by a strain capable of reproducing on cotton, a lesser amount of wilt developed when F. oxysporum was present.

Discussion

The experiments described above indicated that root-knot eelworm was not essential for infection of cotton plants by F. oxysporum f. vasinfectum although when both pathogens were present wilt was more severe. In addition, it was demonstrated that in the early stages of infection the wound resulting from the entry of the larva into the root did not accelerate infection by the fungus, and that damage to the root was not always associated with increased wilt. It appears probable, therefore, that nematodes have effects other than mere mechanical injury.

Young (1938) showed that the incidence of cotton wilt in the field could be reduced by the application of potash ferilisers, or compound fertilisers containing high levels of potash. But in the absence of potassium, nitrogen and phosphate increased the incidence of wilt. The effect of potassium on wilt was, however, obscured when root-knot eelworm was also present. Oteifa (1951 & 1952) working with Lima beans found that potassium stimulated the reproduction of Meloidogyne incognita, and that the potassium content of leaves of plants heavily infested with root-knot eelworm was significantly decreased in comparison with the uninfected control plants. Other elements were not so affected. Thus it appears that potassium can reduce the severity of cotton wilt and that in Lima beans, at least, root-knot nematode induces a potassium deficiency in the host.

The effect of root knot on the nutrition of the cotton plant has yet to be determined. Work on these lines is planned and it may provide a little more information on the mechanism by which Fusarium wilt of cotton is increased by root-knot eelworm.

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CONTROL OF FOMES ANNOSUS IN BRITAIN TODAY

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There is a vast literature on Fomes annosus, the cause of root and butt-rot in conifers, and perhaps I should apologise for adding yet another paper. However, the fungus is of enormous importance in British forestry and control measures for it are far more intensive and widespread than for any other forest disease here. Delegates, therefore, may be interested in a brief review of our work so far and in seeing the stage our control measures have reached.

Fomes annosus is widely distributed, especially in the northern coniferous belt, being found in many states in Canada and North and Central America and in practically all European countries where conifers are grown. It has also been reported in South Africa, India, New Zealand, and various Asian countries, including China and Japan.

The fungus attacks mainly conifers, but also many broadleaved species planted on affected sites. It attacks the roots killing young plants of any species and pines of any age on alkaline and old arable sites, which especially favour its growth. It can cause heart rot of the stems of most of our important conifers, growing up from the root systems, and this possibly is its best known and most investigated aspect. The death of roots which it causes has important effects on wind-firmness of plantations and also on the increment of the trees. These latter two aspects have been little investigated so far but we are becoming increasingly aware of their importance. However, its activities as a butt-rotter alone would still give it pre-eminence in European forest pathology and would warrant intensive work on control measures. It is generally agreed to be the most important tree disease in western Europe. In Germany, Zycha (1954) writes "Losses from Fomes annosus probably reduce the annual yield of timber by 10-15 percent." In Sweden, increasing losses are reported. We hear from personal communications that the butt-rot losses alone amount to about £4,000,000 annually and that in Norway spruce they represent 6% of the total volume. As far back as 1934, Tikka described infection figures in North Finland of 6-12% in Scots pine and 10-40% in Norway spruce in certain stands. Kangas later worked in the southern half of the country and concluded that every tenth standing conifer was attacked by the fungus. Rattsjö and Rennerfelt express concern at the damage done in Sweden and mention losses in volume of 14% and in value of 23% in certain areas. Studies by Petrini and Arvidson respectively have demonstrated losses in the stumpage value of 10% and 20-30% respectively.

In Britain, Rishbeth has calculated that the overall losses due to killing of pine by Fomes in East Anglia amount to £1 per acre annually and may amount to £5 per acre on alkaline sites. Elsewhere in this country surveys carried out by Forestry Commission Research staff have shown very high figures for butt-rot in individual forests. At Kerry in North Wales, 80% of the trees in a twenty-eight year old

stand are infected. At Lael in Ross-shire, 60% of the stems in a European larch stand have stain or rot. These are representative of our worst cases but there are many other areas where disturbingly high figures of up to 50% can be found.

The position would be bad enough if these figures were to remain constant and represent the disease intensity in the future. Unfortunately this is not so. The position is deteriorating and infection is becoming more general throughout the country as a whole as well as increasing in individual stands.

The evidence for this lies in what has been found out about the biology and spread and development of Fomes in recent years. The foundations were laid by Rishbeth's work on the dying of pines in East Anglia in the nineteen-forties. This showed that the main method of spread by Fomes, apart from subterranean mycelial spread in root systems, was by air-borne spores. These are produced on the typical Fomes brackets, growing generally at the base of affected trees. The air-borne spores can germinate on the surfaces of newly cut stumps and the mycelium grows downwards through the stumps into the roots. Thus, due to the regular provision of stumps during our normal forestry operations and the ability of the fungus to colonise them, Fomes is enabled to cause new site infections. If the stumps are in a felled plantation then mycelium from the infected stump roots can pass into the roots of the replacement crop when the latter grow out sufficiently to make contacts. If the stumps are in a thinned plantation then infection can similarly pass over into the roots of standing adjacent trees through existing root contacts or fusions. Then root-rot, death of the tree, butt-rot, or windblow can result according to the species of tree involved and the site factors.

During the last few years experimental and observational work has confirmed that stump infection by air-borne spores is the main method of Fomes spread in Britain generally as well as in East Anglia and in our important butt-rot species as well as in pine, where the effect is usually killing. Other infection methods are known. Extraction wounds on roots and stems, brashing wounds on the stem, infection of the roots of windblown trees, and the use of infected material for fence posts have given rise to new infections, but the stump is by far the most important method of entry.

The most disquieting result of our survey work is the strong evidence that the disease is steadily extending. This is, of course, what one would expect in view of the regular thinnings carried out in our woods and the consequent regular supply of stumps. Indeed, it is difficult to think of any measure that would favour the cause of the fungus more than this practice. Since about 1920, the Forestry Commission has been steadily acquiring and planting land, a vast proportion of which did not previously carry a tree crop. Such ground was, therefore, free of Fomes and remained so through the early stages of the first rotation crops until stumps were provided by thinnings or to a lesser extent by rack cutting, removal of Christmas trees, etc. We have clear evidence of the invasion of these new crops by spores blown from sources where the fungus is well established. There is no possibility of isolation giving immunity in this country. Spores have been found in all parts of the country and even well out at sea. We are faced, therefore, with the inescapable conclusion that new plantations must inevitably be colonised by the fungus as thinnings proceed. Along with this there is ample evidence to show that the degree of infection in any site tends to increase with time. Comparisons of losses in earlier rotations have always shown them to be less and usually considerably less than in succeeding rotations. We have not found a single case where infection has decreased.

The problem then is twofold. First, we must find out how to treat infected sites either by eradicating the fungus or by accepting it and using modified silvicultural techniques such as short-term crops or limiting ourselves to certain species. We have no answer to the eradication problem though experiments are in progress. If there is an answer it is likely to involve considerable work or expense. We envisage that something like complete stump or root removal would be required. The other half of the problem is the protection of uninfected or lightly infected sites. Fortunately, the area involved here is the larger one and a highly effective control has long been known. This consists in painting the surface of the newly cut stump with creosote, thereby keeping the fungus out of the stump which is its main avenue of entry into new ground. This method of control has been standard practice in East Anglia for some years, but not elsewhere. Our recent work has been concerned with introducing stump protection

throughout the country generally. This has been accomplished by detailed surveys in scores of forests and estates, spore sampling to show the presence of the fungus, and wide publicity of the danger. Now stump protection is being increasingly carried out and we can foresee its general adoption as a normal forestry operation so that wherever a conifer is felled the stump is treated.

This is the most widespread and intensive control of a tree disease ever undertaken in Britain and is likely to remain an integral part of our forestry practice. For this reason I have ventured to describe its background and its present position to delegates.

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RADOPHOLUS ROOT ROT OF BANANAS

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Summary

The development of lesions in the cortex of the cord roots of bananas, leading to extensive root destruction, unthriftiness and poor anchorage of plants in the soil, is a major problem in Australian banana growing areas.

High populations of the burrowing nematode, Radopholus similis (Cobb) Thorne, infest the soil that surrounds failing banana stools. Stained, longitudinal section of affected roots show third stage larvae or adult females of this nematode in the intercellular spaces at the periphery of the lesion.

Where R. similis alone is introduced into pots containing banana seedlings established in steam sterilised soil, root lesioning and destruction follows. Pathogenicity of the common fungi isolated from root lesions, namely F. oxysporum, forma roseum and moniliforme, and Rhizoctonia solani, has not been established. That R. similis is the primary pathogen in New South Wales of root rot is further indicated by the effective field control of the disease obtained by preplant soil fumigation with either of the nematicides ethylene dibromide or D. D.

Burrowing nematodes recovered from soils surrounding affected bananas failed to infect any of 27 potted citrus species or varieties inoculated. This, and the freedom from infection of citrus roots growing amongst infected bananas, suggests

that the local R. similis is of the banana race and, unlike the citrus race, appears to have a restricted host range. The nematode has been recovered only from soil which has grown plants of the genus Musa or sugarcane in the 4 years prior to sampling.

Disinfesting planting material by immersing all planting material in water held at 55°C. for 30 minutes, and the planting of only virgin areas or areas which have been freed of bananas for more than 5 years is proposed as a method of control in New South Wales where the terrain of plantations procludes the effective use of soil fumigants.

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Discussion following papers by I. A. S. Gibson & N. A. Goodchild, A. Riggenbach, and R. A. Fox.

S. D. GARRETT (U. K.) congratulated Mr. Fox on his historical survey and was particularly interested in his appraisal of Napper's work. Napper was greatly gifted with imagination and insight and when first confronted with the root disease problem on rubber in Malaya he threw out a number of inspired speculations, for some of which there could have been little evidence at the time. It is thus not surprising that some of these should now be seen to have little foundation, such as his suggestion that cover crop roots exercised a baffling effect, causing the advancing rhizomorphs to split into innumerable tributaries and hence delaying the attack on the roots of young rubber trees. He had always thought that Napper's greatest contribution was his method of post-planting control of root disease by regular collar and root inspection. Although the recent experiments described by Mr. Fox strongly suggest that Fomes lignosus is favoured by soil disturbance, which seems to outweigh the good effect of inoculum removal, the great value of Napper's contributions to root disease problems in general will long outlast the immediate practical value of his discoveries. In the meantime, the apparent effect of soil disturbance is of extreme interest and brings the white root disease of rubber into line with various diseases of field crops, the great majority of which are favoured by good soil aeration.

Dr. Garrett then asked three questions concerning Dr. Gibson's paper: (1) Did Dr. Gibson think that failure of ring-barking to control Armillaria mellea was due to the failure to kill the root system, or to the fact that A. mellea is not necessarily kept out of a killed root system through prior colonisation by saprophytes? (2) How does this query apply in particular to the case of Grevillea robusta shade trees that he cited? (3) How far did he think, from his general experience in E. Africa, that

failures of ring-barking were due to inadequate supervision? If the outermost zone of functional wood is cut through the effect will be the same as clear felling.

I. A. S. GIBSON (Kenya) said that (1) there is evidence that bad ring-barking may have contributed to those outbreaks associated with the removal of shade to a greater extent than was originally thought. (2) So far there is no evidence to suggest that ring-barking may kill the roots of Grevillea robusta and preclude invasion by A. mellea as it does in other trees. (3) At first there was a widespread lack of understanding of ring-barking, particularly among junior staff.

J. C. F. HOPKINS (U. K.) asked if there was any difference in virulence between rhizomorphs of A. mellea established in a natural balance and those where disease occurs.

I. A. S. GIBSON replied that rhizomorph activity seemed equally widespread in tea, forest plantations, and indigenous forest, according to environment, and that no correlation of this with pathogenicity had been found. No comparison of the pathogenicity of isolates from saprophytic and parasitic sources had as yet been made, but this will be done in the future.

R. W. RAYNER (Kenya), commenting on the abundance of rhizomorph formation observed by Dr. Gibson, said that while working on coffee at a somewhat lower altitude A. mellea attacks were sometimes seen but he had never encountered rhizomorph formation. He wondered whether the sporophores seen by Gibson were the annulated form or the exannulate form known as Clytocybe tabescens.

I. A. S. GIBSON said that the sporophores observed by him were of the normal annulated A. mellea type and that no sign of C. tabescens had been found. Rhizomorphs are only formed in relatively wet, low temperature sites and are rare in areas such as those investigated by Wallace in Tanganyika or coffee plantations in E. Africa.

I. W. CALLAN (U. K.) remarked that it is not surprising that Dr. Riggenbach's bioassay tests should show the organo-mercurial tillex to be much more active against Fomes lignosus than copper and organic non-mercurial fungicides. What was surprising was that tillex gave good control in the field, since it is well known that organo-mercurials are rapidly inactivated in the presence of soil. He understood that tillex had been tested at the R. R. I., Malaya, and had been found to be ineffective.

R. A. FOX (Malaya) said that the efficacy of tillex had been tested at the R:R. I., Malaya, in two ways. First, trees were inoculated on lateral roots close to the collar, which was then drenched at the recommended and at double the recommended concentrations. Second, trees were inoculated on lateral roots four feet from the collar and drenches were applied at the same two concentrations four months later when rhizomorphs appeared at the collar. Neither treatment prevented infection of the collar. Regarding the persistance of this compound, plots of two soil types were watered with double the recommended concentration of tillex. Soil samples were collected at weekly intervals and the growth rate of F. lignosus through them was compared, under standard laboratory conditions, with that through soil from control plots which had received plain water. Growth was not prevented, though it was reduced to roughly one half at the end of the first week, and by the end of the fourth week inhibition of rhizomorph growth was practically nil.

S. D. GARRETT did not see why the performance of one fungicide should differ appreciably from that of another when used in conjunction with Napper's post-planting inspection and eradication method for young rubber. Almost by definition, the fungicide is virtually a supernumerary precaution if superficial rhizomorphs are pulled off and infected root sections pruned away. According to our modern concept of inoculum potential, the fragments of mycelium which remain after this treatment are most unlikely to be able to cause renewed infection, whether or not any fungicide is applied to the treated roots.

Discussion following papers by D. A. Perry, J. S. Murray, and C. D. Blake

C. J. MAGEE (Australia) said that Dr. Blake's paper gave an interesting lead to the banana root rot problem. They had incriminated a virus and an aphis vector in connection with bunchy top, but rotting of the roots was also part of the story. He found it interesting that root rot can occur in any open sandy soil, even light volcanic, and that wherever the bananas were moved Radopholus was carried with them. He could recall investigating banana leaf fall in the 1930's; it occurred in the cooler months and many fungi were isolated. N, P, & K fertilizers were tried and regular application of these prevented the disease.

J. B. LEBEAU (Canada) enquired about the hypothesis that nematicides had no anti-fungal action, in view of the fact that complete control of Curvularia on grass had been achieved with a nematicide in the U. S. A.

D. A. PERRY (Uganda) said that he had not tested any himself and so was not prepared to speculate on the control of fungi by nematicides, but he believed that they had almost no fungicidal activity.

J. W. BLENCOWE (Ghana) asked for information on the invasion of felled trees after the stumps had been burned, and whether this was a possible alternative to creosote.

MR. LOW (U. K.) said that this had been the practice in Britain in the past, but the had no personal experience of it; it was known that when pine crops were accident tally burned, killing attacks of Fomes annosus could originate from the burnt stumps.

R. A. FOX (Malaya) remarked that about 50% infection occurred when rubber stumps were burned.

C. G. DOBBS (UK.) asked if there was now any information on the permanence of protection given by stump creosoting. Did it last until the rest of the stump and root system had been colonised by saprophytic fungi, or did it merely postpone invasion by F. annosus?

R. A. FOX said that when a rubber tree is dying, either naturally or after poisoning, there appeared to be a critical period of unknown onset and duration during which it may be colonised by wind-borne spores of F. lignosus and other root pathogens. The spores cannot infect a living tree (it is assumed that their inoculum potential is far too low) but at some stage in the death of the stump they can colonise it, and at this time they have a competitive advantage over the spores of saprophytic fungi. The term 'colonise' is preferred to 'infect'. The onset and duration of this phase, and its site on the stump, are currently being investigated, and it has been found that creosote treatment affords considerable protection. The top of the creosoted stump, as judged by its hardness and lack of decay, is effectively preserved for from 2 to 5 years, the length of time depending upon the luxuriance of leguminous creepers, used as cover plants in the inter-rows, and which, if they grow over the stumps, will provide conditions which hasten decay.

J. S. MURRAY (U. K.) said that stump creosoting will give more than 90% protection until such times as other organisms can occur.

A. GHAFFAR (Pakistan) asked whether Mr. Perry had found Rhizoctonia solani or Macrophomina phaseoli associated with wilt of cotton.

D. A. PERRY replied that F. solani is found on seedling cotton plants in E. Africa, but it is not associated with Fusarium wilt in mature plants. M. phaseoli had not been found.

B. L. CHONA (India) said that in certain parts of India M. phaseoli had been found to be the most serious cause of root rot of cotton, resulting in wilting of the crop.

July 18 afternoon

Seed Pathology

Chairman: Dr. F. Joan Moore

SEED PATHOLOGY – RETROSPECT AND PROSPECT

Mary Noble
Department of Agriculture for Scotland

RETROSPECT

It may surprise some of my audience to know that the problem of seed-borne disease was raised at the 2nd Commonwealth Mycological Conference in 1929. At that conference, thirty years ago, a discussion was held on "seed-borne diseases with special reference to (a) standard methods of determining percentage infection, (b) standard methods of seed treatment, (c) legislation governing the export and import of seeds". A resolution was passed to the effect that "research work relative to the important question of seed-borne disease be given increased attention throughout the Empire, if necessary by the appointment of one or more specialists to the respective plant pathological services, and that such investigations be co-ordinated with the duties of seed-testing stations". Again in 1948 and in 1954 similar recommendations were made.

To go back even further than 1929 may I recall that it is now over 200 years since Tillet demonstrated seed-borne bunt in wheat! About the same time Jethro Tull, in England, made a sound observation which I shall recall later in connection with quarantine work: "In some sorts of seeds the goodness cannot be known by the eye" and again Sir John Sinclair's remark of 1792 still applies to oat seed on the Scottish market today - "The clearest and best-looking oats when sown often produce the worst crop". However, to return to modern times, in the reports of the five commonwealth mycological conferences, there are clear statements of the principles on which work on seed-borne disease should be conducted. There are also reports of work in progress and such names as Pethybridge, Moore, Muskett, Dillon Weston, Brett, and Cunningham guarantee its soundness. Apart from these conferences a session on seed pathology was held at the Jubilee meeting of the British Mycological Society in 1948 when our guest speaker was Dr. Lucie Doyer, the first chairman of the Committee on Seed-Borne Disease set up by the International Seed Testing Association, and the author of the Manual for the Determination of Seed-Borne Diseases, edited by the International Seed Testing Association and published in 1938. Professor Muskett chose this subject for his presidential address to the British Mycological Society in 1950 and meetings convened by FAO, EPPO, and OEEC have all discusssed the problem in recent years. In 1950, an official report published in London on the qualitative control of seed included the question of seed-borne disease. In 1957, a second similar report appeared, that of the Committee on Transactions in Seeds, and in December, 1959, Her Majesty's government announced that "we intend as soon as possible to implement those recommendations which can, without other action, be given effect by revising the regulations under the present seeds act". Such recommendations include some on seed-borne disease. Apparently therefore progress in seed pathology on a United Kingdom basis now has official approval. Obviously, work has been going on at home and abroad whose quality is above reproach but the question now is whether the quantity of such work is commensurate with the size of the problem. I personally think it is insufficient to meet the demands of this United Kingdom report and grossly inadequate considering the resolutions, exhortations, recommendations, and hopes expressed internationally during the thirty years which have elapsed since 1929.

In 1954 my colleagues Drs. Neergaard and de Tempe and I were asked by the

5th Commonwealth Mycological Conference to compile a comprehensive, annotated list of seed-borne diseases. Although this was a much more onerous task than the preparation of the unannotated list which we were at that time planning we accepted the assignment and four years later, in 1958, the list was published jointly by the Commonwealth Mycological Institute and the International Seed Testing Association. Now many imperfections of this publication are already quite obvious to us, and some are already corrected in my working copy, but we trust that readers will be kind enough to send their corrections and amendments to me or to the Commonwealth Mycological Institute in the expectation that a revised version may be called for. This list forms the first chapter of a handbook to be published by the International Seed Testing Association. My colleague Dr. de Tempe is particularly active in this project.

Now that this list of seed-borne organisms is available for reference the two-part resolution made in 1954 may be recalled, the Conference considering there was need "(1) for developing standard methods for the rapid and accurate determination of as many seed-borne diseases as possible and (2) for surveys to be made to discover areas where seed-borne diseases of the various economic crops are at a minimum, with the object of encouraging the production of commercial seed of the highest standard of health".

The development of standard methods was, as already mentioned, the main reason for the publication by Dr. Doyer in 1938 of the "Manual for determination of seed-borne diseases". Although this was an international publication the methods described were, in general, those already in use at Wageningen in the State Seed Testing Station of the Netherlands. From Ulster we have also had most valuable contributions to the literature of methodology of seed pathology. Nevertheless, from Canada in 1951 Wallen and Skolko wrote ... "The reason for ... lack of uniformity in methods of disease diagnosis may be attributed primarily to the development by individual laboratories of seed testing methods especially suitable to their own requirements, facilities, and personnel. Standardization has undoubtedly also been hampered by the fact that comparatively little is known of the seed-borne phases of many of these organisms, the failure to develop satisfactory methods of detection for seed-borne pathogens, and the emphasis on the empirical application of seed testing procedures for their control, with the consequent neglect of fundamental information as to how seed treatment is operative. As a consequence of the differences in seed testing methods, misunderstandings are inevitable and proper interpretation of reports is not possible". Anyone who has been concerned in certification of seed for export or import must agree with this statement and I am glad to say that the International Seed Testing Association's plant disease committee, whose chairman is Dr. Paul Neergaard, is now working to hasten the day when misunderstandings will not be inevitable and proper interpretation of reports possible. This co-operative work within the International Seed Testing Association is directed first towards those seed-borne diseases which are already widespread with their host plants and affect field planting value. The results obtained in the laboratory tests are, wherever possible, related to field planting value in each country. Thus it is possible to show geographically the very important differential effect of soil and climatic conditions on seed-borne organisms. New methods as well as old are studied and in due course those which are found to be applicable internationally will, it is hoped, be accepted for use in issuing certificates under the International Plant Protection Convention as well as for the International Seed Testing Association. Commonwealth countries actively taking part in this work are Australia, Canada, New Zealand, Southern Rhodesia, and the United Kingdom. The Netherlands and Denmark, are, of course, contributing generously. Dr. de Tempe went to Israel recently and Dr. Neergaard to the Lebanon, bringing expert knowledge of seed pathology to bear on seed problems there. Austria, Eire, France, Portugal, Sweden, and the United States of America are all also co-operating and three international conferences of the "work-shop" type have been held since 1958.

PROSPECT

Application of Methods

(a) Quarantine

While the International Seed Testing Association is working to achieve international agreement on assessment of field planting value of seed it may be considered whether full and proper use is being made of methods already available. The simplest is surely that to which both Jethro Tull and Sir John Sinclair made rather back-handed reference - that of "visual inspection"! The limitations of this method, examination of the seed without incubation or germination, should not utterly condemn it, especially as a very large proportion of the phytosanitary certificates for seed are at present based on examination by "visual inspection"! As Mr. Moore stated at the last conference this is at present often the only practicable course. I would again quote Mr. Moore, "Under these conditions the certificate is often worth little more than the paper it is written on", but the fact remains that we do know some diseases and pests detectable by this method! Unless a country specifies complete freedom from any particular seed-borne disease the I. P. P. C. certificates issued from Scotland and England are given on a tolerance basis; "substantially" healthy means not more than 5 per cent of all diseases seen when the seed is examined under a binocular microscope at a magnification of approximately ×20. Thus mangel seed with 4 per cent Phoma betae is passed, but if in addition 2 per cent of the clusters bear sori of Uromyces betae the sample is failed, this in spite of the fact that incubation would probably reveal more than 4 per cent Phoma.

At a meeting in Paris in 1954 an attempt was made to bring about agreement in the wording of I. P. P. C. and I. S. T. A. certificates. Dr. Briejer, in an article in FAO Plant Protection Bulletin some time ago, compared health certificates with bank notes saying the working did not matter, the important thing was the efficiency of the inspection or the financial stability of the bank. Would it be too much to ask that we test the rate of exchange of our currency by direct comparison? We in Scotland export mangel and kale seed to New Zealand and Australia and would gladly arrange to send appropriate samples direct to the Phytopathological Service along with a copy of our detailed reports. In the case of mangel seed just quoted we could, for instance, compare notes on our ability to detect Phoma betae and Uromyces betae. This kind of comparative testing even if only done on a very limited scale between Commonwealth countries exporting to each other would surely provide very valuable information complementary to that arising from the I. S. T. A. comparative testing, the latter being aimed chiefly at assessing field planting value. I would further urge that health certificates based on visual examination only should bear a statement to that effect as an additional declaration or endorsement. Surely this could not detract from the status of the model certificate of I. P. P. C., whereas the continued use of this form of certificate for seed with no such endorsement has already brought it into disrepute.

With regard to the health certificates issued under the rules of the I. S. T. A., not one has been requested in Scotland since 1953. This may be because at that time it was decided by I. S. T. A. that the sender of a sample must specifically ask for a health test and furthermore must specify for which disease or pest the seed is to be tested. if, during the purity or germination test, diseased seed or seedlings are observed no statement to that effect can be entered on the certificate; unless it has been asked for.

(b) Surveys

The resolution of the 1954 conference still stands. Surveys have been made in several countries, notably Northern Ireland and Canada , but I am sure we are all agreed that more work of this kind is needed. In Scotland we have made limited surveys of cereal seed and found that the seed is often heavily infected by disease. Statements to that effect were published but no reduction of demand seemed to follow! On the other hand complaints and loss of trade followed the 1959 season when Scotch grown oats were sown in England and in Eire without treatment by

organo-mercurial disinfectants. We have known for quite a long time that oat seed from Scotland is often infected by Helminthosporium avenae. The recent surveys showed that even more often there was double infection by Helminthosporium and Fusarium nivale. We also discovered that wheat seed is often infected by Fusarium nivale and Septoria nodorum which under Scottish conditions results in diseased crops. I should perhaps mention at this point that this survey work was made by methods other than visual examination. Disease-free oat grain can be grown in Essex but the bushel weight is low, it is "small in the pickel", and for sowing in Scotland is no improvment on northern grown seed of high bushel weight properly disinfected. Our survey work has therefore convinced us that with proper disinfection home-grown oat seed is preferable to some imported disease-free seed.

For some crops we already know where to get disease-free seed. Professor Muskett's survey work has shown how healthy flax and ryegrass seed of good quality can be grown in relatively dry areas of England. In peas, however, disease-free seed from the best seed growing areas of the world is sometimes affected by physiological disorders, one of which is marsh spot. This seed may grow perfectly in the genial climatic conditions ideal for pea "seed" growing but fail to withstand the more rigorous conditions good for production of the crop, especially when grown for freezing or canning. This problem, illustrating a very important principle, is being studied now within I. S. T. A., and Commonwealth countries partaking in this particular work on peas are Australia, Canada, New Zealand, and the United Kingdom.

SEED PATHOLOGY

The examination of seed for disease is now recognised to be a specialised problem. The recommendation of 1929 referred to "specialists" although the 4th Conference in 1948 discussed what kind of person should do the work and then recommended that a "mycologist or plant pathologist should be attached to official Seed Testing Stations within the Commonwealth". The National Institute of Agricultural Botany at Cambridge followed this recommendation by creating a new post of "seed pathologist". Whether it be a plant pathologist, entomologist, mycologist, or seed analyst who is to become a seed pathologist they must be allocated working time. If a new post is created, as at Cambridge, all the better, but seed pathology cannot be expected to make other than very slow progress until it is recognised that as a branch of plant pathology special study and time must be allocated for its execution.

Much has been asked of the International Seed Testing Association and I hope you agree that much has been given; but of the few people available some are carrying on the work of seed pathology nationally as well as internationally on quite an unofficial, informal basis. There is a very definite limit to the time which such people can devote to investigational work and to making known its results because of the demands of routine. I trust that participating government departments will recognise the need for time and opportunity to be given officially for this work and may I, in conclusion, remind you that next year is FAO "Seed Year" and that seed pathology is recognised by FAO as having a contribution to make to the effort to raise seed quality.

UNIFORMITY IN SEED HEALTH TESTING*

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Attempts in establishing workable standard routine seed health testing methods have

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* Authorized for publication on May 17, 1960 as Journal No. 62 by the Faculty of Agricultural Sciences of the American University of Beirut, Beirut, Lebanon.

been made since 1957 through activities of the Committee on Plant Diseases of the International Seed Testing Association. Schemes of comparative testing of infected seed have been organized, comprising referee samples of barley, cabbage, carrot, crimson clover, flax, maize, oats, rice, trefoil, wheat and zinnia. The methods having been used are primarily the following: records are taken after having incubated for a certain period of time the seeds sown on moistened blotting paper, on an agar medium, in brick-stone or sand. Certain seed species were tested for seed-borne spore load by counting spores in a suspension prepared by a specified standard procedure; barley was examined for loose smut by the embryo count method. A total number of 35 stations in 26 countries have participated in these tests.

The major result of the experiments is an appreciation of the possibilities of achieving comparable and reproducible results from different laboratories in routine testing of seeds for disease. The comparative tests as well as three conferences on seed pathology have contributed essentially to improvement of testing techniques, involving such problems being taken up as uniform composition of media, selection of optimum incubation temperature, level of humidity, role of the light factor, length of the incubation period, difficulties in identification of organisms, conflicting interpretation in recording incidences and in evaluating their significance.

Any international approach to the study and control of plant diseases speeds progress. Conscious as we are being today about this need, international technical cooperation has become a field of its own centered in coordinating intergovernmental organisations such as FAO and ISTA and also EPPO and other regional plant protection organizations acting under the International Plant Protection Committee.

It is natural that these organized efforts are focused primarily on one set of activities: development of methods - methods of improving crops, methods of preventing losses. This policy in agricultural science should also apply to efforts of controlling seed-borne diseases.

Before going into a discussion of some problems of methods pertaining to seed pathology I should like briefly to remind you of the different aspects of this special field of plant pathology and seed technology.

Seed pathology has four important aspects.

First, "reconnaissance", bringing about surveys, accumulating information on occurrence of seed-borne diseases, their relative significance and geographical distribution. The Annotated List of Seed-borne Diseases, published recently by the Commonwealth Mycological Institute and the International Seed Testing Association jointly, is an account of the achievement in this respect.

Second, etiological studies, concentrating on the mechanisms and development of seed transmission, with emphasis on the host-parasite interactions and the relation of environment to development of infection in the seed and the subsequent crops. The investigations of Brefeld (1903) on blossom infection of barley loose smut are classical within this scope. The studies of Wilson, Noble & Gray (1945) on the blind seed disease is a more recent outstanding contribution to the general biology of seed infection and seed transmission.

A third aspect, development of routine seed health testing methods, seems to be be blazing a new trail in the science of seed-borne diseases; methods of diagnosis are being improved, and new possibilities of practical control recognized.

Finally, a fourth aspect is the investigations on control of seed-borne diseases, including particularly the techniques of chemical seed treatment. Here is accumulated perhaps the major bulk of data within the field of seed pathology.

In discussing seed health testing the interdependence of these disciplines must

be kept in mind. Co-operation between specialists studying seed-borne diseases from these different angles is imperative and should be encouraged.

In testing seed lots for presence of inoculum that may be harmful to the subsequent crop we have two main purposes in mind; evaluation of the seed quality in terms of planting value, and inspection of the seed for quarantine purposes. These different aims may be decisive as to the selection of methods to be used.

(1) Evaluation of seed quality in terms of planting value. This requires as a prerequisite the development of a reliable technique for qualitative as well as quantitative recording. Furthermore, it requires that interpretation of the planting value be based on experience gained in the light of field performance of related seed lots in the place where the seed is going to be used. The planting value of an infected or infested seed lot may vary considerably from one region to another. For instance, Phoma lingam (Fr.) Desm., the black leg organism of cabbage and other crucifers, occurs in about 20% of the cabbage seed lots grown in Denmark but practically always as very weak infections, the infection percentage being below 1 in 80% of the infected seed lots. The parasite has no practical significance for cabbage crops under conditions prevailing in Denmark. Dutch cabbage seed lots, usually more infected than Danish, may therefore be sown in Denmark without risking much damage. In warm temperature regions, however, such as Southern Europe and United Staties, the fungus may produce disastrous attacks late in the season, on the maturing crop.

(2) Inspection for quarantine purposes. Quarantine inspection has to be carried out according to provisions given by the importing country. As the situation stands today, this usually leaves a wide margin of interpretation to the inspecting agency. If the country having issued the provisions does not specify quarantine requirements but requests in a general way that the seed be "substantially free" from "injurious diseases and pests", it is left to interpretation what is "substantially" and what are "injurious diseases or pests". On the other hand, if organisms are specified, what is then, for instance, "substantially free" from, say, Botrytis cinerea, a ubiquitous fungus actually named in the quarantine regulations of one country?

If introduction of a seed-borne disease into a country is expressly prohibited according to its plant quarantine provisions, no tolerance should be allowed. The seed must be tested and certified as being entirely free of the related inoculum. The result of an inspection is, however, completely dependent on the methods being used and the number of seeds being tested. Practically no quarantine provision in existence gives any precise indication of procedure to be followed in testing for specified organisms. In most cases the very good reason for that is a lack of basic information on standard procedure.

The need of standard routine methods for detecting seed-borne diseases was clearly pointed out by the First Working Party on Seed-borne Diseases convened by EPPO, Paris, 1954. The Report states:

"ISTA should be encouraged to embark on a policy of building up, disease by disease, internationally acceptable instructions on testing methods. It is a long-term programme and the sooner it is started the better. No testing method should be recommended until it had been proved to be generally applicable as the result of 'referee tests' carried out in as many laboratories as possible. Once that had been done, every importing country would know, when they received a health certificate in respect of that disease, just how the seed had been tested and the basis on which the certificate had been issued".

In 1957, the Committee on Plant Diseases of ISTA initiated the organization of a scheme of international comparative seed health testing as a first approach toward establishment of workable standard routine testing methods. In May, 1958, 10 co-operating stations having tested a total of 16 referee samples of 4 important crop seed species, a report (Neergaard 1958) dealing with the results was circulated and discussed at the First International Conference on Seed Pathology at Cambridge.

The Conference was an unquestionable success. Tests of the referee samples of the scheme and samples of a number of other seed species were set up in advance for inspection by the members of the Conference, giving invaluable material for the discussions on results and new possibilities. The great value of this procedure, testing of referee samples and subsequent discussion of results in conjunction with personal mutual checking of interpretation and procedures during laboratory sessions, was so evident that this procedure has become a declared permanent major project of the activities of the ISTA Plant Disease Committee.

A second series of comparative tests was organized in 1959 and a report (Neergaard 1959) discussed in a second conference held in Edinburgh, June 1959. A third series was organized last winter during my stay as visiting professor at the American University of Beirut, Lebanon, and the report (Neergaard 1960) discussed in a third conference held in Beirut, February 1960.

May I give a brief account on the material and methods used in those schemes, the results obtained and the problems and perspectives emerged from these activities?

A synopsis of the seed species and methods applied and the number of stations co-operating in the individual comparative tests is given in Table I. In the series of 1958, 3 samples each of oats, cabbage, carrot and flax and 4 samples of barley were distributed and one common method suggested for the testing. In the series of 1959 and 1960 it was thought preferable to send out one sample of each seed species (in some cases a mixture of different infected lots) with suggestions for 2, 3, or 4 common methods to be used. The total number of stations having participated in one or several of these tests amounts to 35, representing the following 26 countries (1, 2, or 3, stands for the series of 1958, 1959, and 1960 respectively; an asterisk indicates participation in the conference dealing with the series in question).

Afghanistan (3), Australia (2, 3), Austria (2*, 3), Canada (1,2*,3), Denmark (1*, 2*, 3*), England (1*, 2*), Ethiopia (3*), German Democratic Republic (3*), France (2*, 3*), Holland (1*, 2*), Iran (3), Iraq (3*), Israel (2), Italy (3*), Jordan (3*), Lebanon (3*), Libya (3), New Zealand (2*, 3), Northern Ireland (1*, 2*, 3), Pakistan (3), Portugal(1*, 2*,3), Scotland (1*, 2*, 3), Southern Rhodesia (3*), Turkey (3*), Union of South Africa (3), and U.S.A. (1*,2*,3).

The methods which have been used are primarily the following:

1. Blotter. The seeds are sown on moistened blotting paper in Petri dishes. Incubation at 20-22°C. Record 6-7 days after sowing for percentages of seeds or seedlings infected.

2. Agar plating. The seeds are plated out on a specified agar medium, malt extract agar and potato dextrose agar having been suggested in the instructions. Incubation at about 22°C. Record of all colonies, whether saprophytes or parasites, grown from the seeds, 5-7 days after plating.

3. Brickstone. (Or a smiliar inert medium: vermiculite, perlite etc.), used primarily for cereals. Incubation at 14°C. Recorded at 14 days after sowing, with special attention to development of symptoms on the seedlings.

4. Sand. Also used primarily for cereals. Incubation at about 14°C., record about 14 days after sowing, with special attention to development of symptoms and to discoloration due to fungous stains.

5. Spore Count. A spore suspension produced by shaking a given number of seeds in alcohol, which is then evaporated, and the dry sediment suspended in 1 ml. lactic acid. Drops of a known size (0.01 ml.) are examined for numbers of spores.

Table 1

Seed species and methods used in the international comparative seed health testing schemes 1958-1960 organized by the Committee on Plant Diseases of ISTA

Seed species	Method	No. of co-operating stations 1958	1959	1960
Avena sativa oats	MA	9	10	-
	PDA	1	12	-
	Blotter	1	2	-
	Brickstone	1	9	-
	Quartz sand	-	1	-
Brassica oleracea cabbage	Blotter, 2,4-D	9	-	-
	Blotter, light	2	-	-
	Blotter, darkness	1	-	-
	MA	2	-	-
Daucus carota carrot	Blotter	9	-	-
	MA	4	-	-
Hordeum vulgare barley	MA	6	2	-
	PDA	-	13	-
	Blotter	1	15	-
	Spore counting	1	-	-
	Embryo counting	1	11	-
Linum usitatissum flax	MA	9	15	-
	Blotter	2	15	-
	Blotter, darkness	2	5*	-
	Blotter, light	2	5*	-
Medicago lupulina trefoil	MA	-	15	-
	Blotter	-	15	-
	PDA	-	1	-
Oryza sativa rice	PDA	-	-	10
	PDA, surface serilized	-	-	7
	Blotter	-	-	17
	Spore counting	-	-	11
	Rice Meal Agar	-	-	1
Trifolium incarnatum crimson clover	PDA	-	15	-
	Blotter	-	15	-
	Blotter, darkness	-	5	-
	Blotter, light	-	5	-
	MA	-	2	-
Triticum vulgaris wheat	MA	-	17	-
	PDA	-	11	-
	Brickstone	-	11	-
	Blotter	-	3	-
	Quartz sand	-	1	-
Zea mays corn, maize	PDA	-	-	20
	Blotter	-	-	19
	Blotter, 28°	-	-	14
	Sand	-	-	1
	Perlite	-	-	1
	Vermiculite	-	-	1
	Brickstone	-	-	1
Zinnia elegans	MA	-	16	-
	Blotter, 2,4-D	-	16	-
	Blotter	-	16	-
	Soil	-	1	-
	Water agar	-	1	-

*) According to information given during the Edinburgh Conference

6. Embryo Count. Used for detection of loose smut infection in barley. By chemical procedure, the embryos are removed, sieved and examined for presence of the mycelium.

A number of variants of these methods and other methods were used by individual stations.

The major result of these experiments is a clear appreciation of the possibilities of achieving comparable and reproducible results from different laboratories in quantitative routine seed health testing. The complexity of developing a technique in this field is, however, fully recognized by the participants of the schemes but the difficulties can be overcome. In this respect it is interesting that more agreement was found between results from stations that had experience in laboratory seed health testing than between these and results from less experienced stations. Furthermore, progress in producing comparable results has been made by stations after having participated in conferences on seed health testing.

It is to be expected that seed lots containing one or a few easily identifiable organisms will give more comparable results than will seed lots with a large range of organisms, saprophytes and parasites, which complicate identification. In the series of 1959 very "good" results were obtained in testing trefoil for Ascochyta imperfecta Peck, particularly by using the agar plating method. In the 1958 series very satisfactory results were obtained in testing cabbage for Phoma lingam (Fr.) Desm. (blotter, 2,4-D). On the other hand, testing of individual seed lots of oats for presence of different species of Fusarium gave a wide range of species names and percentages in the series of 1958 (agar plating method), whereas the oat seed lot used in the 1959-series yielded better results in respect to Fusarium owing to the predominant presence of an easily distinguishable species, Fusarium nivale (Fr.) Ces. (agar plating method). Very satisfactory results were also obtained in testing flax (series of 1958 and 1959) - two decades of experience in Belfast on the Ulster method (Muskett and co-operators) in identifying a large range of saprophytes and parasites was of great benefit to the international testing schemes. In the series of 1960, in which a large number of stations participated for the first time in co-operative seed health testing, satisfactory agreement between results was particularly obtained in testing maize seed for Fusarium moniliforme Sheld. The testing of rice for a range of seed-borne organisms aroused many interesting problems but also gave encouraging results. The three methods used, agar plating, blotter and spore count, were supplementary to each other. Good agreement was found in the figures from blotter for the major parasites of the seed lot, Helminthosporium oryzae van Breda de Haan and Piricularia oryzae Cav. On potato dextrose agar the latter fungus was only occasionally developed in the tests - other media (decorticated rice meal agar?) may be more suitable. In the spore count test satisfactory agreement was obtained for several fungi, but only 2 of 11 stations participating in this test reported Epicoccum sp., although this fungus was abundantly present as spores in the suspension and easily detectable as demonstrated during the Conference - how difficult to know how to see!

The problems in developing uniformity in seed health testing are due primarily to (1) the variations in conditions of testing from station to station, (2) to difficulties in identification of organisms and (3) to conflicting interpretations in recording organisms and diseases as well as evaluating their significance.

The variation in conditions of testing can be counteracted only by precise establishment of all pertaining details of a standard procedure. Some of these details relate to the medium to be used, the incubation temperature, the level of humidity, the light factor and the length of the period of incubation.

For the agar plating method the preferable medium may differ according to the seed species with regard to the fungi involved. MA and PDA, having been tried extensively in the cooperative tests, were found suitable for testing many kinds of

seeds. There is, however, considerable interest in looking into the possibilities of using a synthetic agar medium that would render a maximum of uniformity as to chemical composition. A synthetic medium would also enable a range of modifications according to possible special needs.

Uniform incubation temperature has reliable thermostatic control as a technical prerequisite. The selection of incubation temperature is important in relation to the origin of the seed, as pointed out by the Beirut Conference. The general optimum temperature range for the manifestation of fungi will be higher for seeds from warm temperate and subtropical regions than for seeds produced in cool temperate regions.

The moisture level has been taken too much for granted in the comparative tests and special precautions should be considered. During the Conference in Beirut, it was reported that the relative humidity of the air during the testing of the referee samples was around 40% in Southern Rhodesia and as low as 25-30% in Ethiopia.

Attention also should be paid to the light factor which has a bearing on the fructification of many fungi, for instance Helminthosporium avenae Eidam. Finally the question of the length of the incubation period must be approached by recording the referee tests at different times, a procedure to be taken up more in future comparative tests than has hitherto been done.

In the comparative tests the identification of different species of Alternaria and Fusarium caused particular difficulty. The same is true about distinction, based on cultural characters, between Alternaria tenuis on one hand and certain other fungi (Helminthosporium oryzae, Phoma sp. on flax, other species of Alternaria a.o.) on the other hand. The activities of the testing schemes are here a help to gaining experience.

The personal element in recording is perhaps responsible for the main part of the discrepancies encountered. The discrepancies may be due to difficulties in assessing slight infection of limited growth or sporulation on agar plates or in blotter tests, either because they are overlooked or - in the case of some fungi - because they are deemed too unimportant to be recorded. Such problems can be settled only through international co-operation.

Another great difficulty in the interpretation of the results is the evaluation of the significance of the organisms and diseases encountered, i.e. the establishment of tolerances. This complicated matter, so dependent on local conditions for development of the diseases in the subsequent crop, has not been taken up by the Plant Disease Committee of ISTA. But practices in approving or rejecting seed consignments submitted for inspection with request for a health certificate, vary greatly from one inspecting agency to another and from one country to another. By establishing standard procedures for the testing we may soon be ready for an approach toward standardization of tolerances as well.

May I in ending this report extend a cordial invitation, or rather a strong plea, to mycologists and plant pathologists in all Commonwealth countries to join the activities of our international seed pathological team. The problems we are taking up are complicated but the tests we launch are basically simple; instructions on techniques are given, colour transparencies of symptoms, organisms etc. are avilable to supplement written descriptions, and the test can usually be accomplished within a couple of weeks. We need the cooperation of colleagues in all parts of the world if ever we are to achieve uniformity of testing seed for diseases; because seeds move today in commerce all round the world.

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THE PRESENT STATE OF HEALTH TESTING OF SEEDS

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SUMMARY

Seed pathology has during many years remained a relatively neglected aspect of official seed testing. Whereas plant pathological knowledge concerning seed transmission of pathogens was steadily increasing, the introduction of this knowledge into routine seed testing did not keep track. Still seed health testing in connection with the sowing value of seeds is only locally practised, and in connection with quarantine purposes the investigation as a rule is only superficial.

Recently, however, attention in seed health testing has grown so that now every seed analyst apparently is convinced of the importance of seed health in connection with the practical value of seeds. This, of course, does not imply that every seed analyst is really doing something about it.

It should not be denied that seed health testing is complicated and difficult, and that its results are not always satisfactory. Its practical value, however, should not be judged by the figures obtained in recent comparative health testing under the aegis of I.S.T.A. In this referee-testing analysts have taken part that were lacking sufficient experience with a certain infection or equipment for its detection. Then it is not to be expected that figures will show uniformity. On the contrary, the practical value of seed health testing should be judged by means of the results obtained in certain laboratories with the pathogens and the methods that workers in those laboratories are acquainted with. Then most certainly the picture will make a more favourable impression.

METHODS

The two main methods of seed health testing, those with a broad applicability, are based on the two main diagnostic principles of general plant pathology which have been adapted to the purposes of seed testing, to wit the moist chamber method and the agar plating method. By choosing appropriate outward conditions and maintaining a rigid standardization of testing circumstances both have been made suited to and have given satisfying results in quantitative commercial seed sample testing.

Although for the quarantine purpose it may occasionally be sufficient to demonstrate whether a certain important pathogen of only local occurrence is present in a seed lot or not, in general for seed testing quantitative information is necessary.

In the Wageningen Station the main method of seed health investigation is based on the moist chamber principle. In recent years many experiments with the agar plating method have not lead to success as notwithstanding all expedients the loss of Petri dishes owing to Rhizopus contamination remains a serious threat. Apparently the contaminating saprophytical fungi are to a high extent seed-borne. A locally prevalent seed infection with quick-growing saprophytes might explain why in some countries seed analysts stick to the habit of giving the seed a superficial fungicide treatment in advance of testing, although realizing that this is in principle wrong, whereas in other countries workers are quite content with plating the seeds as received.

The main thing in seed health as an aspect of the sowing value of the seed is a close relation between laboratory results and field performance. This relation is sometimes difficult to establish in connection with a progressive disease development in the field, which is strongly influenced by outward conditions. Yet it can be stated that the actual level of the laboratory testing results is of little importance. It does not matter so much whether one succeeds in demonstrating the full infection percentage or only a proportional part of it, if only the results can be reproduced for the same sample. These are the two general requirements for any seed testing method: duplicability of results and a close relation with the field.

LABORATORY AND FIELD CORRELATION

As to this latter item not much progress has been made since Heald's early work with wheat bunt (Heald, 1921). In Wageningen, however, some work has been done concerning root-rotting fungi of spring-sown cereals and concerning grey mould infection of flax (de Tempe, 1958a, b).

Cereals are investigated in our laboratory for Fusarium spp. and Helminthosporium sativum (sorokinianum) in a blotter test. In field experiments it was found that in dependence of the sowing and growing circumstances several percent of seed-borne inoculum were necessary for causing one percent reduction in emergence and yield. The testing circumstances in the laboratory are quite simple in these cases. For Fusarium spp. in cereals, a moist blotter test in darkness is used, and after a certain time the seedlings are judged for the characteristic root browning. On behalf of symptom formation it is necessary to maintain the conditions that are optimal for germination. For this reason we start with a pre-chilling period of 3 days at 10°C, which is followed by 3 days 20°C. Observing the disease on the developing seedlings we determine the percentage of severe infection, viz. infection resulting in worthless seedlings, and that of light infection, viz. infection which does not result in severely crippled seedlings. Thus an effective infection percentage can be calculated, which is to be used for forecasting field performance. If the severity of infection of individual seedlings is evaluated in a so-called "effective infection percentage" of course a much closer relation with field performance may be expected than when simply the total infection percentage found is used.

Helminthosporium sativum may reach high infection percentages in certain varieties of summer barley. Under Dutch climatic conditions it acts almost exclusively as a root-rotting fungus, quite similar to the Fusarium spp. Also for this infection cereals are tested in a blotter test in darkness. Germination is not

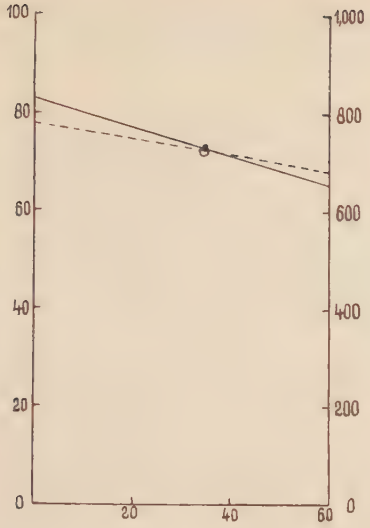

Fig. 1. Influence of seed-borne Fusarium on emergence and yield of summer wheat (field experiment 1955).

Horizontal: seed-borne infection in % according to the blotter test.

Vertical: field emergence in % (left) and yield in grams per 100 seed sown (right).

_____ : field emergence

------- : yield (field-dry plant weight)

Fig. 2. Influence of seed-borne Helminthosporium sativum on emergence and yield of summer barley (field experiment 1955)

Horizontal: seed-borne infection in % according to the blotter test.

Vertical: field emergence in % (left) and yield in grams per 100 seeds sown (right)

_____ field emergence

------ yield (field-dry plant weight)

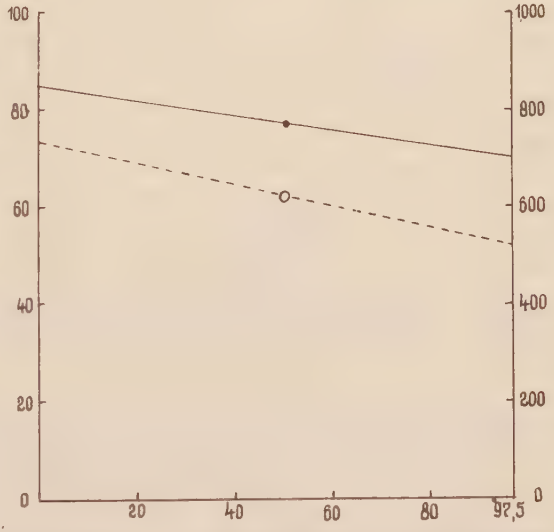

Fig. 3. Fusarium-infected wheat seedlings (blotter test)

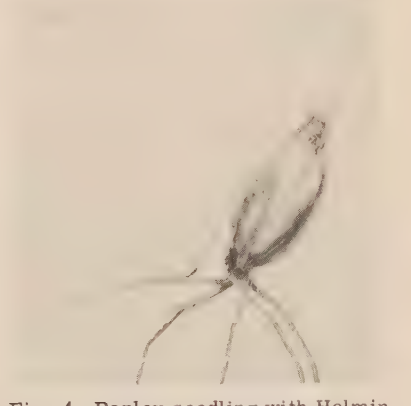

Fig. 4. Barley seedling with Helminthosporium sativum infection (blotter test)

necessary for detecting this infection, for the characteristic sporophores of the fungus will at all events appear on the seed itself. In this case severe infections of individual seedlings scarcely occur, all the infected seeds producing strongly developed but infected seedlings.

Of course, also in connection with these seed-borne infections, agar incubation is a possibility. However, this is not to be realized for cereals unless after surface treatment of the seeds, which restricts the value of the figures. Moreover, with that method we cannot distinguish between slight and severe infections of individual seedlings. It will even be difficult or impossible to draw the line between saprophytic and parasitic Fusarium strains. In the blotter test, on the other hand, it is scarcely possible to indicate which Fusarium species plays a role; only the complex is judged for its prevalence and degree of pathogenicity. However, these qualities and not the latin binomials count in seed testing practice.

In the case of Botrytis cinerea, the grey mould, in flax seed the situation is far simpler for here we only have a single pathogen instead of a complex of ever-changing composition. This does not imply that we are very happy with the blotter test for Botrytis determination in flax, but for the reasons indicated earlier the agar method is not a possibility under our circumstances. So we incubate the blotter trays for 6 days at 20°C. in darkness and then they are inspected for the rotting symptoms evoked by the fungus.

In a number of experiments our laboratory results have been compared with greenhouse and field emergences, and the regression coefficients have been calculated. This can be illustrated with some graphs. Also here the relationship is quite satisfactory, both for emergence and for disease development in the field.

In Wageningen, Van der Spek (1960) has recently studied the Botrytis infection in the seed during storage, using the agar as well as the blotter method for seed health testing. With the blotter method he found a quicker decrease of the Botrytis percentage than with the agar method. This indicates a decline of the fungus preceding its dying-off. In a soil test the observed percentage of infection has a lower level than that found with the laboratory methods, but the relation found between blotter and greenhouse tests was better than that found between agar and greenhouse tests. Apparently, also, in this case, the competition between pathogen and host plant is important for evaluating the seed-borne infection.

Andersen (1959) in Denmark recently studied the infection of grass seed species with Helminthosporium catenarium. He used a blotter test in the laboratory and compared its results with those of greenhouse experiments. In the latter, he found a much higher disease percentage than in the former. Probably the cause of this was that he kept his trays in darkness. Light strongly stimulates sporulation of this and other Helminthosporium species, so that with a blotter test in light a much higher percentage of the seeds will be recognized as being infected. However, it remains to be studied whether the test in darkness or that in light gives a better relation with field performance. The laboratory method showing the better relation is preferable, whatever the absolute level of its results.

The light influence is a factor which has been unduly neglected in seed health testing until recently.

Long ago Dillon Weston introduced the use of ultraviolet light for stimulating fructification of fungi, and Prof. Muskett (1937) applied this expedient for studying Helminthosporium avenae infection of oat seed in a blotter test. Recently De Tempe (1959) studied the stimulating effect of normal light on spore formation by several fungi, and Charles Leach (1959) in Oregon compared the influence of different wave lengths, finding the near ultraviolet most useful.

Of course it is not to be expected that the moist chamber principle, that I seem to be advocating, will be satisfactory for every seed-borne infection to which it might be applied in principle. Personally I have not met with exceptions as I have only studied it closely for those infections for which we have been using it since many years with reasonable results, old items of our routine programme. But Wenzl (1959b) in Austria recently tried it for Cercospora beticola in beet seeds and could not be content with it. The Cercospora disease of beet is prevalent

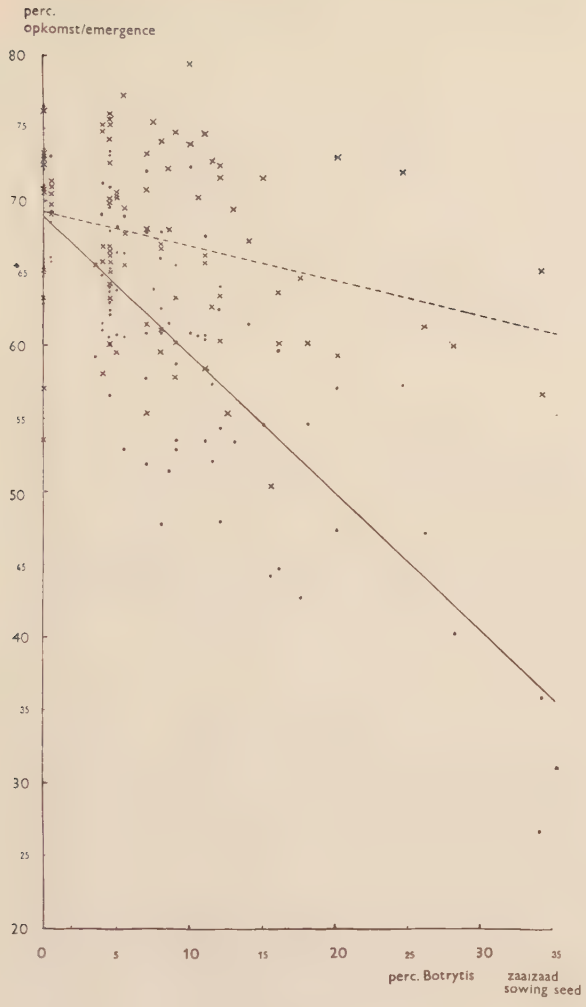

Fig. 5. Influence of seed-borne Botrytis cinerea on the emergence of flax in the field (1956).

Horizontal axis: seed-borne infection in % (blotter test).

Vertical axis: emergence in soil in %

——— untreated

------ thiram-treated

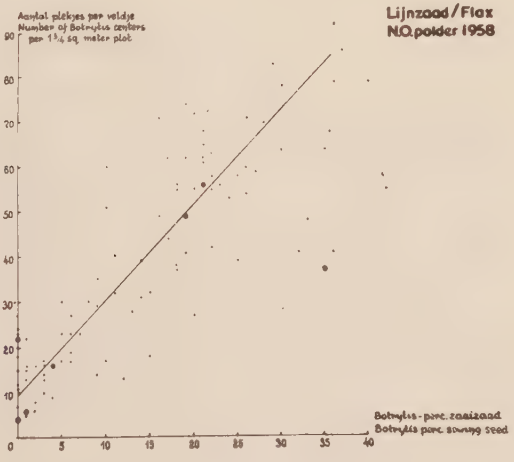

Fig. 6. Botrytis cinerea in flax — Seed-borne infection according to the blotter test (horizontal) and number of disease centers in the field (vertical).

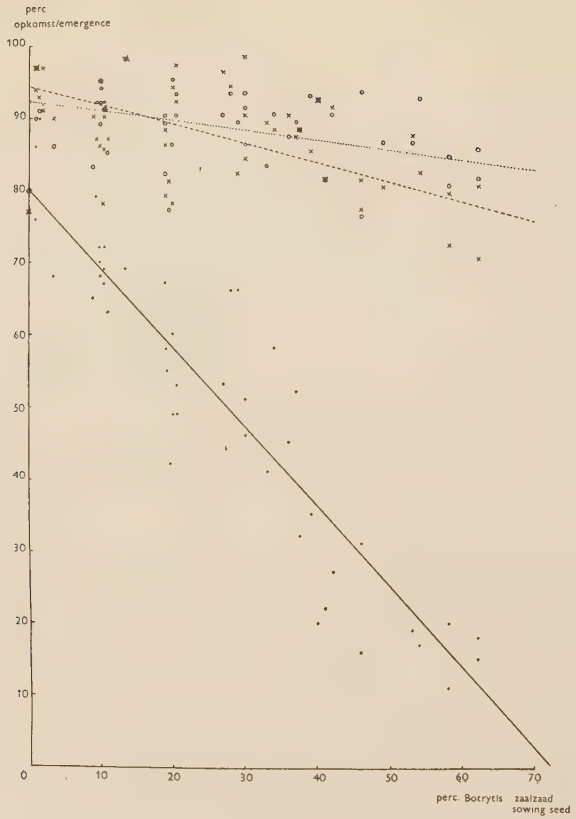

Fig. 7. Influence of seed-borne Botrytis cinerea on the emergence of flax in a greenhouse experiment (1957).

Horizontal axis: seed-borne infection in % (blotter test)

Vertical axis: emergence in soil in %

——— untreated

------ thiram-treated

..... treated with thiram/mercury mixture.

Fig. 8. Helminthosporium catenarium on Festuca pratensis (blotter test)

and important in S. E. Europe. It will at all events appear in a beet crop in the field but seed-borne infection will cause an earlier appearance and consequently greater injury.

On infected clusters the characteristic whip-like spores will normally be present, but the superficial spore infection does not survive until normal sowing time and consequently is of no importance for seed transmission of the disease. However, when infected clusters are kept in a moist chamber for a few days mycelial infection will result in new spore formation and the number of new-formed spores might be taken as a measure for the amount of infection. Wenzl studied this possibility for fresh and old beet seed and found that during storage the capacity for new spore formation decreases rather quickly, which suggests a quick decline of the fungus. Yet in greenhouse experiments a similar quick decrease of the disease percentage in the seedling stage was not observed, so that here the moist chamber principle apparently creates a wrong impression.

DISCUSSION

From these few examples the conclusion may safely be drawn that for choosing a routine method of estimating a certain seed-borne inoculum it is not always right to choose the method that at first sight seems most attractive, or that yields the highest infection percentages.

In germination testing, the principle of optimal germination circumstances, resulting in the highest germination percentages, is quite satisfactory. Moreover, here a sharp line may be drawn between normal seedlings that will produce normal plants under ordinary sowing conditions, and abnormal seedlings that will be worthless under field conditions.

In seed health testing, the situation is more complicated because the severity of infection of individual seeds and seedlings is an arbitrary characteristic and yet important. In relation to the properties of the disease it should be differently evaluated. In general severe infection of an individual seed will prevent emergence of the seedling, so that the injury done will be completed in and limited to the seedling stage. A slight infection of an individual seed, which does not prevent emergence of the seedling, may be far more dangerous in practice because of progressive disease development in the growing crop.

This situation has its implications for fungicidal treatment of seeds. In case of more or less deep-seated seed-borne infections it is often observed in greenhouse and field trials, that after treatment the emergence percentage is increased but also the percentage of infected emerging seedlings is much higher. The consequence of the treatment thus can be a large inoculum in a dense crop, which may be disastrous.

Another disagreeable aspect of mercurial seed treatment may be its phytotoxic effect, which has been measured and expressed in graphs in the experiments with cereal diseases mentioned before (de Tempe, 1958a).

In case of prevalent pathogens of restricted spreading possibilities such as cause those cereal diseases the seed-borne inoculum only is of limited importance for disease development beyond the seedling stage, although its importance in the seedling stage is not obliterated during further development of the crop. In such cases the severity of individual seedling infection, the direct influence on the seedlings that grow or might have grown from infected seeds, is heavily preponderating. On the other hand, secondary spread of the pathogen is more important with diseases such as caused by Ascochyta pisi in peas or Colletotrichum lindemuthianum in beans, so that here a light infection of individual seeds and the seedlings growing from them will develop more severely in the field. Here what is worse for the individual seedlings is better for the crop as a whole because the injury due to secondary spread of the pathogen normally will be far greater than that caused directly to the seedlings that grow or might have grown from infected seeds.

What is more important, the seedling stage or later development, is dependent upon pathogen, host and growing circumstances, and it might even become desirable in evaluating a seed-borne inoculum to take the sowing and growing

circumstances into consideration. Although that might be too far-fetched still it will be clear that the situation in connection with seed health testing is far from simple.

CONCLUSIONS

The International Seed Testing Association now is indicating chosen testing methods for certain seed-borne diseases in an Appendix to the newest edition of the International Rules for Seed Testing.

These specific methods are only intended as methods that have proved to be workable in skilled hands; they are not indicated as the best or even preferable methods. The purpose of their publication in the I. S. T. A. proceedings is stimulating interest and research, and finally routine seed health testing; it is not tying down the analysts on a definite method for a certain seed-borne infection.

Of course, international standardization is desirable in order to obtain comparable results. But this purpose can only very gradually be realized by means of education going hand in hand with study of methods and comparison of results.

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Seed Pathology

Discussion

C. L. A. LEAKEY (U. K.). said that there seemed to be a danger of confusing two separate problems. The purpose of standardization of procedure, emphasized by Dr. Neergaard, is to provide information about the state of seed in the producing area. This information can then be assessed in the planting area as regards which fungi are locally important. The grower's problem is thus that outlined by Dr. de Tempe; he may need a seed pathologist's advice, but the problem is nevertheless a parochial one.

MISS M. NOBLE (U. K.) considered that although many aspects of the problem are complicated, others are more straightforward and can be tackled at once. At Wageningen, this work had been carried on for about 40 years and they had

developed considerable skill, but there was an urgent need for more people to begin. For example, they did not know that Fusarium nivale caused root rot in Scottish soil until they started seed pathology. Mr. Leakey had simply indicated the need for more seed pathologists; both of the problems he mentioned, in her opinion, fell within the scope of seed pathology.

J. DE TEMPE (Holland) agreed that although things were often complicated this should not deter anyone from entering seed pathology. The problem must be tackled and even if results are not perfect, experience with only a single method can be of great practical value. With regard to F. nivale, this tends to occur in seed of northern origin and not in seed of southern origin. If seed from the south is sown in a northern area the fungus is unimportant, but if seed from the north is sown in the same region it may be very important. The prime need is to indicate the consequences of seed-borne infection to the farmer, and assessment methods should be used which will give results closely related to field performance.

W. G. KEYWORTH (U.K.) asked whether there was much information upon which tolerances mentioned by Dr. Noble were based.

J. DE TEMPE said that in Holland, at the Government Seed Testing Station, agricultural samples are tested by the blotter method, and the tolerances for the different seed species and infections are chosen in accordance with what is normal in Holland. This means that only the worst lots are screened off as unfit for a certificate, and occasionally the tolerance levels may even be changed in adaptation to the general harvest quality in a certain year. Thus, in general, tolerances are higher than in other countries, where seed is examined without incubation, but the Dutch method is more reliable. There seems little justification for making tolerances very low. For instance, in the case of beet, buyers do not complain if the seed contains a certain amount of Phoma infection, provided that in other respects it is up to their expectations.

W. G. KEYWORTH said that the question of tolerance seemed to be based on expediency rather than on experimental results.

J. DE TEMPE replied that this may not be right but it is true. For any routine test to be satisfactory, it is necessary that significant differences should be found between good and bad samples as well as between good and bad years.

July 19 morning

Forecasting and Assessment

Chairman: Dr. P. H. Gregory

FORECASTING AND ASSESSMENT, PROGRESS CURVES

E. C. Large
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Our experience has taught us that in plant disease assessment work each disease has to be tackled individually, in great detail, and over a number of years. There is no one method that will serve for all diseases.

There are, however, some general strategic lines which we follow in our investigations. First, we study the normal course of development of the healthy host plant throughout its growing period, with careful descriptive records and drawings of its successive stages. Then we study the actual manifestations of the disease in the field at each of these stages. From this basic information we draw up a field key for the disease. We test this key in the field by a good deal of pilot survey work, with a number of observers. When we are satisfied that the key is sufficiently accurate and easy to use, we seek ways and means of employing it in surveys over the whole country, which continue for at least three years and often much longer.

At the same time we promote field trials to determine the effect of the disease, as measured by the key, on the eventual yield of produce. The results of the surveys and trials are then collated to obtain estimates of disease losses. Forecasting, where it is called for, is an ancillary part of all this work.

Since the setting up of the disease assessment section at our Laboratory in 1950, we, with our associates in the National Agricultural Advisory Service (N.A.A.S.), and elsewhere, have done much work on cereal growth stages, ear populations, and cereal mildew; diseases of forage plants: clover rot, Epichloe in cocksfoot, and Verticillium wilt of lucerne; virus diseases of brassicas, and apple scab. All this work has been, or will be, published in our journal PLANT PATHOLOGY.

To illustrate all that has to be done before we can reach the point of determining national losses from a plant disease, and of operating a successful forecasting system for it, I will run over the course of the work in which I have taken part, on potato blight, pointing out the uses we have made of progress curves, operations charts, and other graphical methods.

When I started as assistant to Mr. A. Beaumont at Seale-Hayne College in 1941, I began by making a careful scale drawing (in fact $\frac{1}{2}$ full size) of a representative potato plant, with all its foliage, roots and tubers at fortnightly intervals from planting to harvest. These drawings illustrated and supported the findings in Paul Murphy's classic paper on the seasonal development of the potato plant in relation to blight attack and spraying (Murphy, 1939). (They also showed up the haulm damage that would inevitably be caused by spraying once the crop had begun to sprawl).

Seizing upon Murphy's point that the loss of crop from blight depends on the time at which defoliation of the haulm arrests tuber production, Beaumont then turned up what records he had of blight on the foliage since 1931, and we produced the first histograms showing the probable (or possible) losses that blight had caused in Devon and Cornwall each year. We used these to promote spraying in our war-time potato spraying campaign (Beaumont and Large, 1944).

It also happened that in 1941 Mr. Walter Buddin of the Disease Measurement Committee of the British Mycological Society (B.M.S.) sent us a tentative key for the assessment of blight on the haulm. We did not like it in its first form, but something of the kind was just what we needed for our survey work. We tried it out; we measured and studied potato plants in all stages of blight attack; and we took the important step of expressing the damage in terms of the percentage of the foliage put out of action for photosynthesis. A revised key was published by the B.M.S. in 1949, and this has stood the test of time.

In addition to our survey and demonstration work, I carried out a series of detailed spraying trials, at Dartington Hall and elsewhere, relating foliage protection and yield. The next important step was the representation of the results of these trials by "progress curves", in which the percentage destruction of the haulm, as measured by the key, was plotted on a time base (Large, 1945). The progress curve completely defined the epidemic. The yield with a defined epidemic on the unsprayed was compared with the yield with an equally well-defined retarded epidemic on the sprayed.

Over the same run of years, I was lucky enough to participate in the spread-of-virus trials organised by Doncaster and Gregory (1948). In these trials there were plots all over the country on which periodic liftings were made to determine the increase of crop fortnight by fortnight through the season. I looked after the ones in Devon, and on some of them I repeated Paul Murphy's experiment - recording the course of tuber production when the haulm was kept completely free of blight by frequent applications of a weak copper fungicide.

Meanwhile, Beaumont was writing up his many years of work on the formulation of the now famous "Beaumont rule" for potato blight forecasting (Beaumont, 1947).

In 1946, when the N.A.A.S. started, Beaumont was transferred to Yorkshire, and I to Cambridge. With the help of our colleagues we both carried on the same kind of spraying trials that we had had in Devon in our respective new regions, for a run of years. Thus we had results of such long-term trials for 1947-51 in

Yorkshire (Beaumont, Bant and Storey, 1953) and for 1948-53 for the area round the Wash (Large, Storey, Taylor and Yule, 1954).

In 1950, when I went to take charge of Mr. W. C. Moore's new section at Harpenden, we were ready to conduct a national survey of potato blight throughout England and Wales. Mr. L. P. Smith of the Agricultural Branch of the Meteorological Office had then recently proposed that blight forecasting by the Beaumont rule should be tried out over the whole country; and the two parts of our work on potatoes, blight surveying and blight forecasting, were very fortunately linked together.

Beaumont periods recorded by a network of fifty standard weather stations in England and Wales each year were entered on an "operations chart" side by side with the dates at which blight reached the 0.1% or "outbreak" stage, as actually found in the field by the N.A.A.S. in the course of the country-wide blight survey. Thus, as the years went on, we learned how to interpret the occurrence of Beaumont periods at the various stations, in relation to the state of growth of the crops and other factors. We now have a method of using our charts that is giving reliable forecasts for our principal potato growing regions year after year (Large 1953, 1956).

But this is only a part of the work; since I last addressed this Conference in 1954, we have confirmed the general accuracy of our method of estimating blight losses from progress curves (Large, 1952); we have been able to divide the whole of England and Wales into a number of "blight zones"; to determine the frequency of severe and slight epidemics in each zone; and to obtain realistic estimates of the blight losses in each zone, and for the country as a whole, over a ten-year period (Large 1958).

We can also estimate the effect of spraying. In the exceptionally bad blight year, 1958, out of a mean potential crop of 8.4 tons per acre we should have lost 2.4 tons per acre from blight if no protective spraying had been done. Spraying about half the maincrop acreage reduced this loss to about 1.8 tons per acre and gave us an average national yield of 6.6 tons. In the exceptional dry year, 1959, out of a potential mean yield of 8.8 tons, we should have lost about 0.2 tons if there had been no spraying. Spraying about one-third of the acreage resulted in a slight increase of this loss - to about 0.25 tons; giving an average national yield of 8.55 tons (Large, 1960).

The whole long story of our work on potato blight in England and Wales, during the past twenty years, with all the principal trial results and practical details, has been drawn together and told in a collaborative study of recent potato blight epidemics throughout the world which has now been published by the Agricultural Research Service of the U.S.D.A. in Washington as their Agriculture Handbook No. 174 (Cox and Large, 1960).

In this study we tried, with the help of our many collaborators in the Commonwealth and elsewhere, to present as much as possible of the available information about potato blight epidemics in the different countries in recent years, and to interpret it by the methods which have been developed in England and Wales.

I would like to draw your attention to the "climagrams" used in this study - another graphical method of investigation. With the help of our Meteorological Office, who put at our disposition all the data in their invaluable tables of temperatures, relative humidity, and precipitation for the world (Meteorological Office, 1958), it proved possible to show in a single, simple diagram for each area, not only the potato growing seasons, but also their relation to the mean temperature and rainfall for each month of the year.

These simple "climagrams" reveal more and more about potato growing in the various regions the longer they are studied. They show for example that in every part of the world the potato cropping season is that part of the year in which the main air-temperature line is over 50°F and under 70°F. They show where overlapping cropping will carry blight over from one crop to the next; where both cropping and blight will be limited by high temperatures; where the best potato yields are likely to be obtained, and also where blight epidemics are likely to be most frequent and severe.

Although we found in our study that the severity of blight attacks, like the level of potato yields, is in practice closely tied up with rainfall, the forecasting of outbreaks demands the special recording and interpretation of humidity data for the area concerned. We reviewed the various temperature-humidity rules, and concluded that success in forecasting depends not so much on the rule adopted as on experience in its use - which is only to be obtained by checking the forecasts against the findings of thorough blight surveys in the field. In England and Wales, where there is a good network of stations recording humidity periods, our "operations chart" method works very well. Where the area is wider and stations fewer, the method of linking a limited amount of special humidity-temperature recording with synoptic weather maps, as developed by Bourke in Ireland (Bourke, 1957) appears to be the most valuable.

Now just a few words about our disease assessment work in England and Wales on another disease of potatoes, common scab. Here the strategy of our attack was the same as on potato blight. First, we evolved a good field key by much preliminary examination of scabbed potatoes. Then we used this key in an adequate field survey: in this case in collaboration with the Potato Marketing Board (Large and Honey, 1955). The survey has continued on some 2,500 crops each year since 1952. As a result of this work we have found out what constitutes an objectionably scabbed potato, where the scab-areas are in this country, and how much of our national potato yield is composed of objectionably scabbed potatoes each year. We have found that there is a very good negative correlation between the percentage of badly scabbed tubers in the national crop and rainfall during the growing period in the scab-areas (Large, 1960). The range is from 5% of scabbed tubers in the very dry years, to less than 1% in the wet years. The graphical representation of this makes another of our diagrams. A simple kind of forecasting comes in here, as, from the rainfall in June, July and August, we can now foretell the general level of scab for the year, in advance of lifting. The conditions for high incidence of common scab are almost the direct opposite for those for potato blight.

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ERRORS DUE TO SPORE DISPERSION IN FIELD EXPERIMENTS WITH EPIDEMIC DISEASE

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To assess the value of a fungicide pathologists compare plots that have been treated with the fungicide with plots that have been left untreated. Usually, these plots are relatively small, and treated and untreated plots lie close together in some statistical design. In an epidemic, the treated plots are bombarded with spores from the untreated plots; and one must ask to what extent the difference brought about by treating the experimental plots with the fungicide would represent the difference which a farmer could expect if he used the same fungicide on his fields. How accurately, for example, does a small sprayed plot bombarded with spores from adjacent unsprayed plots represent a large sprayed farm field, reasonably well isolated from external sources of infection? Also, how accurately does a small unsprayed plot which loses a high proportion of its spores because it is small represent a large unsprayed farm field which loses a low proportion of its spores because it is large? If the representation is inaccurate, then one may legitimately speak of an "error", because the purpose of a fungicide trial is to judge how the fungicide would behave in farm practice.

To answer these questions an analysis was made of the best described fungicide* field trials on record: those of Large (1945) and Large et al (1946) on the use of Bordeaux mixture against Phytophthora infestans on potato foliage. There were trials in Devon and Cornwall during the years 1941-44, of which the trial at Dartington in 1942 is discussed in detail here.

The equations of Gregory (1945) for the dispersion of air-borne spores in conditions of low atmospheric turbulence were accepted because they agree well with the field data compiled from the literature of late blight by Gregory, and also with the data subsequently published by Waggoner (1952). To adapt Gregory's equation for the quantity of spores in a cloud when its centre has moved a distance from its source it is necessary to tabulate

$$\frac{1}{a}\int_{0}^{a} \exp\left[-0.248s^{0.38}\right]ds.$$

This is the proportion of spores removed from a strip of uniformly blighted potatoes a cm. wide by wind moving at right angles to the strip, and uses the parameters determined by Gregory. On the assumption that wind does not change direction during the short time it takes to cross a plot or field it is possible approximately to estimate the proportion of spores removed from a uniformly infected plot or field of any size, shape, and orientation to the wind, and also the proportion of spores removed from one plot and deposited in another.

* Our analysis will be limited to fungicide trials, but applies equally to variety or other trials.

The errors caused by differences between experimental plots and farm fields will be called dissimilarity errors, to distinguish them from sampling errors caused by differences between samples from a population of plots.

Unsprayed experimental plots and unsprayed farm fields.

The plots used by Large at Dartington in 1942 were approximately 20 yd. long and 5 yd. wide. The greatest loss of spores, 19%, would have been when the wind was at right angles to the diagonal of the plot. The average loss for all orientations to the wind would have been 15%. Against this there would have been a gain of 3% from other plots in the experiment, which gives a nett loss of 12%.

The loss from a square 2-acre field would be 2%. This choice of size and shape is arbitrary but not very important because most farm fields would fall in the range of 1 to 3% loss.

The problem is to determine whether the amount of disease in an experimental plot losing 12% of its spores is very different from that in a farm field losing 2%.

The disease progress curve was sigmoid. To straighten a sigmoid curve of this sort one plots $\log \frac{x}{1-x}$ against time (van der Plank, 1960), where x is the proportion of tissue that is diseased. The regression coefficient of $\log \frac{x}{1-x}$ on time (in days) was estimated to be 0.200. This is for a 12% loss of spores. For a 2% loss the figure would be 0.208. This calculation assumes a pre-reproduction period of 90 hours from infection to spore production, which agrees with the results of Crozier (1934) at 18° to 24°. It also assumes that at low concentrations of spores the number of infections is proportional to the number of spores, in which case r′(van der Plank, 1960) is proportional to the number of spores. That spores and infections are in proportion was assumed by Waggoner (1952) for P. infestans, and has been shown experimentally for Puccinia graminis tritici (Petersen, 1959).

Multilpication cannot start in a plot until a lesion is present. One lesion per plot of 100 sq. yards amounts to about 1 part of foliage destroyed in 240,000 parts. If the regression coefficient of $\log \frac{x}{1-x}$ on time were 0.200 it would take 20.5 days for blight to increase from 1 lesion per plot to 5% blight. If the coefficient were 0.208 it would take 19.7 days. That is, blight would reach the 5% level an estimated 0.8 days earlier in a square 2-acre field than in the experimental plot.* This means that, to judge by an extrapolation, the use of small unsprayed plots to represent unsprayed farm fields would cause the yield in unsprayed farm fields to be overestimated by about 0.1 tons per acre. This dissimilarity error is small, but not negligible for two reasons.

First, the experimental plots were fairly large and compact. One cannot assume only a small dissimilarity error for the row-wide plots one sometimes reads about.

Secondly, the dissimilarity error depends on the regression coefficient. Halving the coefficient (i.e. from 0.2 to 0.1) would increase the difference in time of reaching the 5% level of disease about three-fold (from 0.8 to 2.3 days). The less susceptible the variety or the less favourable the weather for disease, the greater is the difference in time. The coefficient in the trials at Dartington in 1942 was the highest of the whole series, so that the dissimilarity error that was estimated is conservative.

Sprayed experimental plots and sprayed farm fields

In the experiment there were 10 spray treatments and 4 unsprayed controls randomized in 3 blocks of 14 plots each. The average loss of spores from a 20 yd. × 5 yd. plot is, as already stated, 15%. The average loss from a square group of 42 plots of this size is 3%. (Even wide variations in the shape of the group

* In these calculations with regression coefficients the error from the memory factor (van der Plank, 1960) is ignored. This factor's effect is negligible in the present context.

do not affect the conclusions materially.) At the time when the Bordeaux-sprayed plots had 0.1% infection, the unsprayed plots had an average of 59%. Therefore, for every 100 spores formed within a sprayed plot an estimated $\frac{12 \times (15-3) \times 59}{41 \times 0.1} = 2070$ spores invaded the plot from unsprayed plots in the experiment.

Because it was in an experimental design with unsprayed plots, the sprayed plot had 21.7 times as many spores per unit area as an isolated* sprayed farm field would have had at the same level of infection. (This calculation neglects the trivial proportion of home-grown spores that get blown out of the sprayed plot.) The regression coefficient of log $\frac{x}{1-x}$ on time (in days) was estimated to be 0.146. This was for the sprayed experimental plot with excess spores. The estimate for a farm field without excess spores would be 0.020. At the relevant time, which was towards the end of August, the rate of increase of foliage blight in an isolated farm field would have been only one-seventh of the rate in the experimental plots. Blight development in the sprayed experimental plots does not give any accurate indication of how blight can be expected to develop in sprayed farm fields. One can only hazard the guess that an isolated sprayed farm field would have stayed free from economicallly serious blight at least until the residues of copper from the final spraying on August 13 had become inadequate, or until the increased susceptibility to blight of the foliage as it aged changed the pattern of blight development+.

The greatest single item in the estimate of the dissimilarity error is the ratio, $\frac{59}{0.1}$, between disease in the unsprayed and sprayed plots. The better the fungicide, the greater the ratio, and hence, other things being equal, the greater is the dissimilarity error. The better the fungicide short of absolute perfection, the greater is the need to protect sprayed plots from contamination by spores from unsprayed plots. This paradox gives the complete answer to the school that believes that extraneous sources of infection should be present in order to allow the fungicide to prove its worth.

Independent evidence for a dissimilarity error

The evidence so far has come from applying Gregory's equations and parameters for low turbulence dispersion of spores. The application assumes that most of the spores that leave the lesions get caught up in eddying air. This seems likely from Hirst's (1958) finding that most spores of P. infestans are released in the morning in sunny spells. Moreover, even if only one-tenth of the spores got free into the eddies, the difference between sprayed experimental plots and sprayed fields would be large. Nevertheless, it seems desirable to mention three independent items of evidence for massive interference with sprayed plots by spores from outside.

Firstly Large found that deposits of Bordeaux were effective only in the early stages of attack and almost lost their effect after 1% of the foliage was visibly affected. (This was true even of freshly applied deposits, as at Dartington in 1953). In other words, when about 1 leaflet in 50 is infected even fresh deposits seem to leave the other 49 as open to attack as unsprayed leaflets at the same level of disease. This finding becomes intelligible only on the assumption of massive interference.

Secondly, a corollary of massive interference is that differences between treatments would tend to be reduced. This was so. For example, full-strength Bordeaux (with 0.25% Cu), half-strength Bordeaux, cuprous oxide, and copper oxychloride showed only small differences in their effect on blight despite great differences in the copper residues on the leaves.

Thirdly, another corollary is that if the blight progress curves in the unsprayed plots were sigmoid, those in the sprayed plots should have become

*Substantial isolation is relatively easily effected when dispersion takes place in conditions of low turbulence, and the concept of an isolated field is tenable.
+Evidence for the effect of age on susceptibility has been given by, among others, Grainger (1956) and Lowings and Acha (1959).

progressively flatter than sigmoid as the epidemic advanced. This effect was, in fact, observed, especially at Kentisbeare in 1942, and was significant for the series as a whole, despite the opposing factors of waning copper residues and waxing susceptibility of the foliage.

Design of field trials

How can one reduce dissimilarity errors?

If unsprayed or inefficienitly sprayed treatments can be excluded (as would happen when, for instance it is desired simply to compare a promising new fungicide with an established standard fungicide) no great problem is involved.

But when sprayed and unsprayed plots must be compared the plots should be reasonably large and square (or nearly so), they should be in line, and the unsprayed plots should have sprayed guard plots on either side of them.

Having plots in one line is not new in statistical design. Wishart and Sanders (1955) have recommended the design for randomized blocks in cultivation and drilling experiments; and even in a latin square the plots may be in one continuous line (Cochran and Cox, 1950). Admittedly, these authors were not considering square plots; but squareness, though it may lead to inconveniently long or broken lines, brings in no new principle. If the line forms part of a general field, the rest of the field must be efficiently sprayed.

Consider the basic segment in such a line with an unsprayed plot (U) between 2 sprayed plots (S) and separated from them by sprayed guard plots (G) (i.e. in the sequence SGUGS). With 10 yd. × 10 yd. plots an average of approximately 0.2% of the spores from the unsprayed plot would fall in the sprayed plots. Doubling the guard plots (to give SGGUGGS) would reduce the figure to 0.06%.

The figure of 0.2% is for the average of all possible orientations of the line to the wind. With wind within 10^{o} of the line the figure is 1.0%. But wind within 45^{o} of the perpendicular to the line would transfer almost no spores from unsprayed to sprayed plots. If there is a prevailing disease-carrying wind, with disease spreading mainly in one direction, the best solution is to put the plots in a line across this direction. If this can be done, not only can the dissimilarity error be reduced but the rule about square plots can be related and the line shortened.

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BLISTER BLIGHT CONTROL IN TEA BASED ON SUNSHINE RECORDS

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Summary

Blister blight (Exobasidium vexans (Massee)) on tea was first found in Ceylon in 1946. It developed rapidly into a major disease and is now controlled by spraying copper fungicides on a large area of up-country and mid-country tea at elevations of over 2,000 feet during the south-west and the north-east monsoons. The cost of blister blight control varies from one and a half to two and a half rupees per acre per spraying round or approximately 3% of the cost of production. The total yearly cost of blister blight control in Ceylon is probably Rs. 10,000,000/-.

In order to reduce the costs a forecasting system based on the fact that sunshine kills the spores of the fungus has been worked out. The frequency of spraying against blister blight on tea is determined according to the number of hours of sunshine received. Based on unpublished work of Visser, Shanmuganathan, and Sabanayagam, the minimum number of hours of sunshine required for sufficient control by sunshine alone is taken as 20 over a period of five days or 16 over four days.

Trials were laid down at five estates. Spraying was done only if the total sunshine during the five days before the date of spraying was less than 20 hours. The number of spraying rounds was considerably reduced in all five trials resulting in an appreciable increase in the incidence of blister blight on only one of the five estates. The reduction ranged from 4 to 12 spraying rounds per total of 20 to 26 rounds.

[cf. Mulder, D. & de Silva, R.L. (1960). A forecasting system for blister-blight control, based on sunshine records. Tea Quart. 31:56-67.]

BLACK RUST OF WHEAT
CO-OPERATIVE INVESTIGATIONS IN WESTERN EUROPE AND NORTH AFRICA

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Epidemics of black rust of wheat have been under close observation since 1947 onwards at the Ministry of Agriculture's Regional Centre at Bristol, since the worst effects are felt in the counties near the English Channel. Wild barberry bushes have been mapped but very few have been found to be near arable fields. Aecidia found on barberries appeared to be of the varieties avenae or secalis.

Following the resolution passed at the 4th International Congress of Plant Protection at Hamburg in 1957, interested specialists met together at Bristol in

January, 1958, and a co-operative scheme was worked out for the study of epidemics. Subsequently, in October, 1958, the first European Colloquium on black rust was held at Versailles.

As a result, epidemics are now recorded every year from North Africa and Southern Europe northwards. This information is passed on to all collaborators in the 'Bulletin d'Information' issued by Prof. L. Guyot of Grignon. Rust nurseries, comprising some 20 to 30 selected wheat varieties or strains used in breeding, are put down in the countries concerned. Records are made of the first occurrence of black rust in these plots and in wheat fields. Rust collections are made in each country and sent to Elvas, Portugal, to be identified for race by Dr. J.C. Santiago. (In England, rust differentiations are also carried out at Cambridge and Bristol).

In England, the Channel Islands, Scilly, Wales and Ireland, 24 nurseries of spring wheats have been put down in 1960. Spore catching, under the supervision of H. A. Hyde, is carried out at Cardiff and Bishop Rock (Isles of Scilly). Traps are also in operation at Paddington and Southampton.

Through the co-operation of W. H. Hogg and the Air Ministry, attempts are being made to trace the origin of the spores by mapping the trajectories of the air masses concerned, while Dr. J.C. Hirst, the aerobiologist, investigates spore catches in the English Channel from flights on likely days, organised by the Air Ministry.

By these means it is possible to detect the early arrival of spores from the south. If these are numerous and weather conditions favourable a warning can be given of an imminent epidemic. Determination and mapping of the races involved adds to our knowledge of the overall distribution of rust races in Europe and assists in the breeding of rust-resistant varieties.

The analysis of results to date will be presented at a black rust symposium in October, in London, and in November at Madrid. They indicate a fairly uniform picture every year of the spread of wheat rust northwards. Certain Commonwealth countries could profitably collaborate in this investigation.

AN ESTIMATE OF THE EFFECT OF SEED TREATMENTS IN REDUCING COTTON CROP LOSS CAUSED BY *Xanthomonas malvacearum* IN UGANDA

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Introduction

Xanthomonas malvacearum, the causal organism of bacterial blight of cotton, may attack any aerial part of the plant. In Uganda, it mainly survives from one season to the next on seed which becomes contaminated as the result of boll infection in the previous season. During the growing period of the crop the bacterium is spread mainly by rain-splash. There is general agreement that the stem phase of the disease is the most important in causing loss of crop.

Although there are high-yielding varieties of cotton resistant to bacterial blight these have not the same lint quality characteristics as the susceptible commercial varieties which the market demands. Therefore, until disease resistance is combined with desirable commercial qualities seed treatment will remain the most convenient and economical method of controlling the disease in Uganda.

Dressing cotton seed with cuprous oxide started in the Eastern Province of Uganda in 1950 and by 1955 all seed planted was treated. Claims have been made (Jameson and Thomas, 1953; Pottie, 1953) that seed dressing has increased yield by 50-75%, but these are not substantiated by the data for either total production of cotton lint or for yield per acre. The total production has fluctuated, with no obvious trend, around 350,000 bales of lint since 1948 - seven years before the whole of the Uganda crop was treated. The comparison of yield between the years before and after seed dressing was introduced is confounded by the introduction in

the Eastern Province in the same year as seed dressing of a new variety claimed to be more resistant than the previous one.

A realistic approach to the problem of assessing improvement in yield resulting from seed treatment was made by Manning and Kibukamusoke (1958). By statistical analysis, they estimated that the average increment from seed dressing was about 9% and this was confined to the Eastern and Northern Provinces where the incidence and severity of bacterial blight are higher than in the remainder of Uganda. In the latter area they found that seed dressing had not increased yield.

This paper presents the results and conclusions from three experiments made during the 1959/60 season to obtain (1) an estimate of the efficiency of seed treatment chemicals in reducing loss in yield, (2) a measure of disease intensity for forecasting loss in yield, and (3) an estimate of the effect of stem lesions on the yield of individual plants. The seed used all came from the same bulk of a multi-line strain of BP52, which was known to be heavily contaminated with X. malvacearum.

Experiment 1.

Experiment 1 was a large-scale trial planted at three widely separated centres. Its purpose was to compare the yields obtained by the use of four mercurial seed dressings with that from Perecot 45, the cuprous oxide compound at present used in Uganda. A fully randomized block layout was used. Plots were 1 acre, separated one from another by 10-foot wide strips of elephant grass to prevent spread of infection between plots. The incidence of infection at each centre was recorded three times. A systematic sampling method was used in each plot to see whether or not infection spread between adjacent plots as the season advanced. The data indicated that there had been no interplot spread of infection. Yield was taken from the whole of each one acre plot.

TABLE 1

	% Hg.	RATE OF APPLICATION (W./W.)	% INFECTION PRIMARY	STEM	YIELD LB./ACRE
AGROSAN	5.0	1:150	1.6	0.7	679
ABAVIT INORG.	4.2	"	6.9	3.3	743
*P.M.U.	1.0	"	6.9	4.7	695
+P.M.A.	1.0	"	9.1	5.6	735
PERECOT	—	1:250	6.2	6.0	694
UNTREATED			67.0		

*P.M.U. = Phenyl mercury urea
+P.M.A. = Phenyl mercury acetate

The results were similar at all three centres. Table 1 summarizes some of the data from Serere in the Eastern Province, where the incidence and severity of infection were higher than at the other centres. All dressings markedly decreased the level of primary infection, Agrosan 5W more than the others, which did not differ significantly amongst themselves. Analyses of the yields for each centre and of the combined yields showed no statistically significant difference between treatments. These results indicate that the 1% organic mercurial compounds, P.M.A. and P.M.U., could replace the more expensive Perecot 45, but that little would be gained by replacement with the still more expensive and highly toxic 5% organic mercurial.

Experiment 2

Experiment 2 was initially designed to compare the efficiency in controlling primary infection of three new seed-dressing chemicals, "A", "B", and "C", against that of three of known performance, Agrosan 5W, Perecot 45 and Spergon. The six treatments were planted at the Cotton Research Station, Namulonge, in five randomized complete blocks, plot size being 1/100 of an acre. After the incidence of infected seedlings was found to range from about 1.0% in some of the Agrosan - 5W - treated plots to approximately 75% in some of the "C" -treatment plots (equivalent to untreated) it was decided to take the trial to yield, in order to estimate the effect of the disease on yield and, at the same time, find a measure of disease intensity that could be related to crop loss. Records of infection on individual plants were made at various times during the season.

The mean yield of over 1,300 lb. of seed cotton per acre, remarkably high for a late-planted crop, was probably achieved because the second rains were above expectation, virtually eliminating shedding of early crop through water-stress, and because insect damage was eliminated by heavy applications of DDT.

A disease index was obtained as follows:- Plants when 16 weeks old were graded for the severity of, and the effect on the plant of, stem lesions originating at the cotyledonary node or the node immediately above, using a grading system which is an abbreviated form of that described by Wickens (1953).

Grade A = a small restricted lesion having no visible effect on plant growth

Grade B = a large lesion, slightly retarding growth.

Grade C = a large spreading lesion, girdling the stem, having either killed or obviously going to result in the death of the stem.

To assess the amount of disease per plot, grades A, B and C were given the rating values of 1.5, 3.0 and 4.5 respectively. The disease index was calculated and expressed as a per cent of the maximum disease possible in a particular plot (see Table 2).

The first indication that the disease was affecting yield came from the correlation of disease index per plot and the mean total number of bolls per plot that the plants held when 20 weeks old. The linear relationship between these two factors accounted for 52% of the total variability, and, on the average, plants with stem lesions held 32% fewer bolls than did plants without stem lesions. However, at the final pick, although the association between disease index per plot and yield per plot was still highly statistically significant, the variability accountable by the association between these two factors dropped to 37% of the total. No relationship was evident between final yield and either leaf or boll infection.

To estimate yield at zero disease index, it was assumed that, as the observed relationship was linear, then the extrapolation to zero disease might also be linear. The calculated yield at zero disease index was 1,495 lb. seed cotton per acre. The difference between this and the yields for each treatment calculated using the regression coefficient represents the losses in yield that might result from the diseases recorded in the various treatments. These losses were expressed as percentages of the calculated yield at zero disease and are presented in the last column of Table 2.

Under the conditions of this experiments stem infection resulting from planting untreated seed caused a loss in yield of 20%, (the 19.1 confidence limits were ±5.7%). Treatment of the seed with Agrosan 5W and Perecot 45 reduced this loss to 8 and 12% respectively, but the difference between these two values is not statistically significant at the 5% level. The significance of this result will be discussed later.

Experiment 3.

The purpose of Experiment 3 was to estimate the effect of stem lesions on the yield of individual plants. This was done as follows. The seed cotton from 150

TABLE 2

Treatment	PRIMARY STEM	DISEASE INDEX	FINAL YIELD	CALC. LOSS
AGE OF PLANTS (weeks)	3-4	7-8	16	
	%	%	%	LB/ACRE	%
A	5.3	1.6	3.8	1342	11
B	16.0	7.4	5.5	1349	13
C (Equivalent to untreated)	68.9	19.6	11.8	1196	20
AGROSAN	0.5	0.6	1.9	1397	8
PERECOT	2.9	1.9	4.7	1321	12
SPERGON	2.1	1.0	2.8	1371	9

plants with either A, B, or C grade stem lesions was picked separately and the weight of seed cotton recorded for each of the 5 picks. The weights from these plants were compared with those from 150 plants, grown in the same plot, without stem lesions.

The results showed that Grade C lesions decreased yield by about 60%. Grade B and A lesions at the second pick caused a loss of 50 and 44 %, respectively, but at the third and fourth picks this loss dropped to 36 and 25%, respectively. Thus both A and B grade stem lesions inhibited the formation of the early formed crop, but the plants later partially compensated for this by producing extra bolls.

Discussion

The fact that the cotton plant can form fruiting bodies for as long as it continues to grow is probably the most important fact in getting a clearer understanding of the reasons for yield fluctuations. McKinlay and Geering (1957) showed that plants disbudded for 12 weeks eventually yielded almost the same amount of cotton as those not disbudded. Thus early crop loss may be compensated by a later crop production.

The plant reacts to adverse conditions, particularly water stress, by shedding damaged or undamaged flower buds or young bolls. Whether or not it can use its potential capacity to recover from early crop loss, depends on where it is growing. - Thus, the two main climatic regions in Uganda, (1) the elephant grass zone, and (2) the short grass zone, must be considered separately. The first, embracing the southern and western regions, is characterised by a bimodal rainfall pattern that generally provides conditions under which bolls can be formed over a period longer than with the more unimodal rainfall of the Eastern and Northern Province. Whether or not the cotton plant can recover from loss sustained early in the season from pests or diseases is also important in considering the economic aspects of using insecticides or seed dressings.

The loss from insect attack on cotton in East Africa has been studied by McKinlay and Geering (1957), Coaker (1954), and Dale and Coaker (1960) with the main conclusion that where the environment does not favour continued crop formation spraying is likely to increase yield appreciably.

Extrapolation from results obtained in one particular season to other seasons is risky, but the results from the three series of experiments, done at four widely separated centres, complement each other and also agree well with those of previous workers. Arnold (1957) and Hansford (1933, 1934) showed that stem lesions suppress plant growth and decrease yield, which is confirmed by

experiments 2 and 3. Hansford found that stem lesions equivalent to the above-described A and C grade lesions caused a crop loss of approximately 25 and 60% respectively; an estimate that agrees closely with that from Experiment 3. However, diseased plants in Experiments 2 and 3 produced more bolls later on than did healthy plants and so compensated to some extent for the early crop loss. These trials were late-planted (in August), and soil moisture became limiting about mid-December. Had the trials been planted at the optimum time of planting (in June) compensation for early crop loss from bacterial blight might well have been greater and even complete. Manning and Kibukamusoke (1958) calculated that seed dressing did not increase yield in the elephant grass zone where the climate favours continued crop formation.

Conditions in the Northern and Eastern Provinces are very different. Manning and Kibukamusoke (1958) calculated that Perecot seed dressing in these areas increased yield on the average by 8.9%, an estimate in close agreement with that from Experiment 2. In these areas early crop loss cannot usually be compensated by later growth, and timely planting to avoid shedding by water-stress, together with insecticidal spraying and seed treatment are all very important to establish and maintain an early crop. Attention must be given to all three, as their effects are complementary.

The value of the disease index will now be discussed in the light of what has already been said. Clearly, this disease index, or any other measurement of disease intensity, will only provide an estimate of crop loss in Uganda when there is no other factor that limits or affects yield. Moisture availability and insect damage have been discussed at some length as these and bacterial blight can have the same end result of causing loss of early crop. Low nutrient status of the soil and poor cultural practices by the farmer are other factors that limit the yield of the cotton crop in Uganda. The situation is complex. Hence the real value of a disease index is simply as a measure of the severity of the disease in a particular area in any one season. This in itself is of value, but not, at present, for providing an estimate of crop loss.

The result of no yield differences between the 5 seed treatments in the large scale trials may be accounted for by either (1) that conditions at all three centres were such that the other limiting factors, water-stress and/or insect damage, had the effect of levelling that caused initially by bacterial blight, or (2) that the difference in the disease index between plots dressed with the various chemicals was too small to affect yield, or a combination of (1) and (2).

The main conclusion from these experiments is that, at present, the problem of seed dressing in Uganda resolves itself into a question of economics. Providing precautions are taken against volatile mercury vapour there is no reason why the cheaper 1% organic mercurials should not replace cuprous oxide, but it seems that no benefit would be derived by replacement with the expensive and highly toxic 5% organic mercurial.

These results and conclusions will be submitted, in full, for publication in the EMPIRE COTTON GROWING REVIEW.

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AVAILABILITY OF *Venturia inaequalis* AND *Venturia pirina* ASCOSPORES IN NEW SOUTH WALES

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The economic loss from apple and pear scab in the highland areas of New South Wales has been estimated at 19% of the annual value of the crop (Hutton, 1955). This estimate, which was computed for the six years period 1948-49 to 1953-54, does not include the cost of applying the sprays, several of which are combined with insecticide applications and cannot be charged specifically against scab control. It does, however, account for unmarketable fruit and loss through down-grading as well as the cost of the cheapest effective fungicides necessary to prevent an estimated annual loss of 80% to 90% of the crop.

Ascospore discharge: The Seasonal Pattern with *Venturia inaequalis*

During the above period, investigations on the discharge of ascospores of *V. inaequalis* were proceeding and as a result of this and subsequent work the control programme has been strengthened to such a degree that it is now anticipated that losses of the above magnitude are not likely to recur. Details of these investigations will be published elsewhere, but briefly it was shown that few perithecia are mature enough to discharge ascospores before the beginning of October which, within the limits of small season-to-season variations, usually coincides with the early pink bud stage of tree development. There is then a rapid increase in maturity of perithecia resulting in a peak of ascospore availability about mid-October, the period of early to full bloom. This is followed initially by a rapid decrease in ascospore availability which then declines slowly through November with cessation of ascospore discharge about the end of December.

To obtain this information infected apple leaves which had overwintered naturally in the orchard were sampled at intervals throughout the season. Ascospore ejection was induced in the laboratory, the spores being caught on glass slides. Direct counts were then made. In the 10 years (1948-49 to 1957-58) during which the measurements were made the peak period of ascospore availability was found to vary between mid-October and mid-November, but in most instances it occurred about mid-October. No ascospore was detected later than the end of January, although Smith (1954) trapped ascospores of *V. inaequalis* in South Australia in March, using a suction trap in the field.

The above period of peak ascospore availability is later in the season than that measured by Hirst et al. (1955) at Wisbech in 1953 and 1954, using the automatic volumetric spore trap which Hirst designed (Hirst, 1952).

The Hirst Spore Trap at Batlow

In the seasons 1956-57 and 1957-58 a Hirst spore trap was operated in a pear

orchard at Batlow, the district most liable to scab of the major pome fruit districts of New South Wales. Batlow is situated in the southern highlands at an elevation of approximately 2,500 feet and has an average annual rainfall of approximately 54 inches. Details of these investigations will be published elsewhere. The following is a summary of the findings.

It was found that the diurnal periodicity in ascospore discharge described by Hirst et al (1955) for V. inaequalis is very well defined with V. pirina, the peak flights occurring about mid-day. When rain began after nightfall no ascospore of V. pirina was trapped until about 9 o'clock the next morning. On the other hand, when rain began in the morning, substantial spore numbers were trapped within the first two hours. When continuous rain occurred with the inoculum initially in a non-exhausted condition, a rhythm of diurnal periodicity in ascospore flights and a progressive exhaustion of inoculum were found to occur.

The daytime mean number of ascospores per cubic metre of air was calculated for each day on which the trap was operated. These figures showed that the seasonal pattern of ascospore availability of V. pirina, as measured in the field by the Hirst spore trap, was essentially the same as that for V. inaequalis as measured by the laboratory sampling method.

No ascospore or conidium of either V. pirina or V. inaequalis was caught when the trap was operated during and after rain in autumn 1956, 1957, or 1958.

From the results obtained in these investigations it has been possible to forecast heavy primary infection during October in the highland pome fruit areas whenever suitable infection conditions occur.

Modification of the Protective Spraying Schedule

As a result of this information the schedule of protective sprays recommended has been intensified through the period "pink bud" (early October) to "first cover" (mid-November), and this has resulted in improved control.

The results have also shown that the pre pink sprays are less significant in New South Wales than previously believed. It has been established in field experiments (unpublished data) that the concentration of the pre pink sprays may be reduced without decrease in control.

A Spray Warning Service

In conjunction with the investigation of ascospore movements at Batlow a warning service was provided for the growers in that district. Mr. P. Henry, then Fruit Officer at Batlow, operated the trap and determined the occurrence of potential infection periods from the weather data, using the method of Mills and La Plante (1954). Growers were advised from their local radio station immediately an infection period had occurred. As Batlow is 340 miles from Sydney there was a delay of 24 hours before the slides could be examined. However, Mr. Henry was advised by telegram of the inoculum level immediately after the examination of each slide and, whenever an infection period had occurred, this information was also broadcast to growers . This proved to be a valuable extension aid in helping growers to appreciate the necessity for urgent action following a warning that an infection period had occurred.

Growers maintained a protective cover on their trees to the best of their ability, but, if caught with an infection period toward the end of a spray interval, they applied a spray of 0.005% phenyl mercuric chloride as soon as possible after the warning was broadcast. Many growers claim to have obtained consistently better control of black spot since this service began.

Acknowledgment

The assistance of Mr. P. Henry in operating the spore trap and recording the weather data at Batlow is very gratefully acknowledged. The co-operation of Mr. M. J. Gedye in allowing his orchard to be used for these investigations is also much appreciated.

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AN ESTIMATE OF THE AVOIDABLE LOSSES FROM PLANT DISEASES IN KENYA

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At the Fifth Commonwealth Mycological Conference in 1954 pathologists frequently observed that the number of plant pathologists in the Commonwealth was insufficient to deal with existing problems, let alone to prevent the introduction of new diseases. If the basic assumption can be made that any one plant pathologist cannot possibly cope with all the problems in the territory, then it becomes immediately important to establish priorities for research and to conserve effort for those of the major problems on which research can be expected to yield results which can be measured in terms of economic benefit to the territory by a valid increase in the territory's agricultural product. In the case of Kenya, Robinson, in a paper in the EAST AFRICAN AGRICULTURAL JOURNAL, has listed recently no less than 140 diseases of crops as being of economic importance, and in the present survey Robinson's list has been taken as a starting point.

At every stage in the preparation of an estimate of this kind so many assumptions have to be made that the final estimate can be no more than an approximation which can be used as a working guide, and at the outset it was decided, therefore, to include in the survey only those crops which were grown on an area of 10,000 acres and above. There are thirty crops which thus come into the survey, starting with maize, which is being grown on $1\frac{3}{4}$ million acres, beans and sisal on $\frac{1}{2}$ million acres, wheat, millets, cassava, and sorghum on $\frac{1}{4}$ million acres, down to groundnuts, sunflower, rice, and cashew nuts growing on between 10,000 and 15,000 acres.

Having established the crops on which disease losses were to be assessed, the next stage was to take each crop in the list and using Robinson's records of the important diseases of each crop to classify the diseases according to the system used by the Colonial Plant Disease Survey. Each disease was placed into one of three categories, a, b, or c, after an arbitrary decision as to whether the losses caused by it were over 10% of the crop, between 2% and 10% or an average of 1% only. To this figure, the formula proposed by Watts Padwick (1956) at the last Conference was then applied, to compute the gross losses being sustained by each crop as a result of all the diseases to which it was subject. There was an immediate difficulty here in that, for instance, not all of the maize crop within Kenya was suceptible to head smut or to white blight, to mention two of the class (a) diseases, and thus the crop total acreage figure could not be used as a basis for the computation. Instead, the computations were made having regard to the known distribution of each disease at the beginning of 1960. All of you who know Kenya and the wide climatic range in which crops are grown will realise how inadequate distribution data must be, even taking into account the extensive records prepared by my predecessor in office, Dr. Nattrass, which I was fortunate in being able to use.

However, approximate figures for the total percentage loss brought about by diseases were obtained for the thirty most important crops in this way, and the next stage was to reconsider the list of diseases of the thirty major crops and again divide them into three categories. Into category (i) were placed those diseases for which no prospect of control could be foreseen, or which could be controlled in ways which were uneconomic to apply in terms of the value of the crop and land values. Category (ii) contained those diseases on which work was worth while since it may possibly result in the formulation of control measures which it would be economically feasible to apply. Category (iii) consisted of diseases for which economically valid control measures could be foreseen if work was done.

Category (iii), included some diseases for which control measures exist already and are being applied in other countries but which either have not been evaluated in the range of climate and soil conditions of Kenya or are being inadequately applied, and which can reasonably be expected to work well once the preliminary laboratory and field work has cleared the way to the establishment of satisfactory control measures.

All diseases which fell into this third class were designated as preventable losses. It might be mentioned in passing that enough diseases fall into this category to keep the plant pathological section of the Department of Agriculture fully occupied for the next five years.

Taking the preventable losses as a group, these were then used as a basis of a fresh calculation, again using Watts Padwick's formula to make an estimate of the preventable losses.

The next stage was to place a monetary value on the preventable losses; firstly, a monetary value had to be given to the crop turnover by adding to the recorded cash value of marketed products the equivalent value of the portion of the crop grown as food and consumed outside the recorded cash value. Once this figure was obtained it became possible then to think of expressing the preventable losses not only as percentages, but in equivalent cash value. Thus, for maize, the equivalent cash value of the 1957 crop was £21 million; total losses brought about by diseases to the maize crop were 26%; separate calculation of preventable losses showed them to be of the order of 5%, and their equivalent cash value to be of the order of £1$\frac{1}{4}$ million.

Using this method, it was possible to arrive at a figure for the total equivalent cash value of the entire agricultural product of Kenya, using figures supplied by the East African Statistical Department. In 1957, the figure for the total equivalent cash value of the agricultural product of Kenya was £70 million. Our calculations showed the equivalent cash value of preventable losses brought about by disease on the thirty main crops to be £7 million: in other words, the turnover would have been £77 million had all the losses been prevented.

An analysis of the methods of preventing these losses which will emerge, or have already emerged, shows that one quarter of the losses are preventable by spraying, one quarter can be expected to come from the general adoption of disease resistant varieties, either already produced or anticipated from the plant breeders, rather less than one quarter will come from improved agricultural practices, very notably crop rotation in the case of nematodes and soil borne diseases, and the remainder can be expected to accrue from the correct application of fungicidal seed-dressings for the prevention of soil and seed-borne diseases.

As far as spraying is concerned, almost all the losses come from coffee leaf rust and coffee berry disease and the work of the Colonial Research Unit, headed by Dr. Nutman, holds promise of an early and dramatic improvement in the level of control achieved on the Estates. The use of resistant varieties, notably rust-resistant wheats coming from the Plant Breeding Station but with many other improved varieties of crops arising from local breeding schemes or imported, has already contributed and will do so in an increasing way during the next few years. Not as much progress can be hoped for from improved agricultural practices, particularly with indigenous cultivation tied closely to the cash and food economy, but with seed-dressings, progress promises to be rapid, although it will take time to establish correct seed-dressing routines.

There is a very large follow up problem here, for once the correct seed-dressing routines have been established for fungicidal and insecticidal components the methods have to be established practically, both at peasant level and by a more critical approach to large scale machine dressing. With some crops, notably millets and sorghum, and maize in hot soils, we find that we are further back in development work than we would wish since there is so little in the literature about the use of seed-dressing on these crops and in these conditions.

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Discussion following papers by E. C. Large, J. E. van der Plank, and D. Mulder & de Silva

P. H. GREGORY (U.K.) said that in field experiments, infection coming from the outside and infection spreading from within were two different factors. The small, replicate plot scheme is based on the supposition that treatment of one plot will have no effect on the others. While this holds good for laboratory experiments with flasks and test tubes and for fertilizer field trials it does not apply to above-ground epidemic diseases, where the problem needs a special approach.

B. L. CHONA (India) considered that comparative plots are necessary, but it should be remembered that fungicides used as sprays may have a stimulatory effect, while seed treatment may increase yields by 10-15%. In assessment work in S. India on sugarcane it was found that, with the variety grown, even a 100% mosaic infected crop suffered less than an 8-10% impairment of quality.

Discussion following paper by L. Ogilvie

C. J. MAGEE (Australia) was pleased to learn of the intensive study now being made of black stem rust in S. W. England and S. Europe. The frequency of severe attacks is much higher than in Australia. He drew attention to the paper which would be presented later on behalf of I. A. Watson of Sydney University reviewing 40 years' work on the disease in the southern hemisphere.

Discussion following paper by C. Logan

I. W. CALLAN (U.K.) noted that although the various seed treatments used in Mr. Logan's trials gave appreciable differences in disease control, these were always compensated for by late-formed bolls and there were no differences in ultimate yields. Did these late-formed bolls produce the same quality cotton as the early-formed ones, and did their harvesting involve any additional labour and expense? Perhaps the actual value of the crop might give a more reliable measure of the benefit of treatment than does gross yield.

C. LOGAN replied that after being picked the cotton was separated into two grades, clean and stained lint. The different seed treatments showed no effect on the proportions.

Discussion following paper by K. E. Hutton

L. OGILVIE (U.K.) asked if there was any carry-over of conidia of *Venturia* on the twigs in addition to ascospores.

C. J. MAGEE (Australia) replied that in Australia there was very little, if any, conidium formation on twigs and that Dr. Hutton had never observed a carry over from season to season in this way.

M. H. MOORE (U.K.) said that the situation in Australia seemed substantially the same as that obtaining in this country, in that the main danger period from ascospores was from mid-April throughout the bloom period, although some ascospores matured and were disseminated earlier. Hitherto we have, probably unwittingly,

employed the curative action of lime-sulphur with good results, and mercury compounds are now deliberately used to the same end. It must be stressed that spraying should be even more efficient and thorough when used curatively than when used protectively, because there is less time for effective redistribution.

I. F. STOREY (U. K.) remarked that in Australia the pattern of ascospore distribution as shown by spore trapping follows closely that of normal spore ripening. This is probably due to the high incidence of days on which rain falls. In English orchards the pattern is affected by the occurence of dry spells during the period of ascospore release, when large numbers of ascospores are trapped in the perithecia until the onset of rain releases them. Hence, in some years the pattern of ascospore concentration in the air may bear little relation to their normal pattern of ripening.

July 19 afternoon

Fungicides

Chairman: Dr. C. J. Magee

THE COMPARISON OF THE EFFICACY OF ANTIMYCIN, BLASTMYCIN AND BLASTICYDIN 'S' WITH MERCURIAL FUNGICIDES FOR CONTROLLING BLAST OF RICE

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Copper based fungicides have been in the past the main stay in the control of paddy blast, caused by the fungus Piricularia oryzae Cav. They are, however, ineffective under epiphytotic conditions and often show phytotoxic symptoms of leaf scorch and yield reduction. The fungicide ferric dimethyl dithiocarbamate (subsequently referred to as F. D. D. C.) which is presently used in Ceylon was very much less phytotoxic than copper while showing about the same efficacy. During the last 9 years organo-mercurial fungicides have gained wide popularity in Japan owing to their spectacular efficiency. A dust formulation of phenyl mercuric acetate (P. M. A.) and lime being used extensively. Unfortunately, at its effective concentration of 0.25% mercury P. M. A. proved highly toxic to a large number of indica varieties grown in Ceylon (Marks & Peiris, 1959). Of the other mercurials tested the ethyl mercuric dusts, ethyl mercuric chloride (ECL), and ethyl mercuric phosphate (EMP) though non-phtyotoxic were somewhat ineffective and much inferior to P. M. A.

Recently, the antibiotics antimycin, blastmycin, and blasticydin "S' have revealed promising blast control properties in Japan. Unfortunately, however, antimycin is highly toxic to fish life and blasticydin 'S', the most promising of the trio, is toxic to japonica varieties. In these series of experiments the efficacy and phytotoxicity of these antibiotics in controlling blast on Ceylon indicas were compared with the commercially available organo-mercurial fungicides.

Materials and Methods

These fungicides were screened under natural epiphytotic conditions, artificially induced on highland nurseries (Peiris & Marks, 1958) in the blast susceptible variety Pachcha Perumal 2462/11, which has consistently shown resistance to the phytotoxic action of P. M. A., the most potent of the phenyl mercuric fungicides. The percentage leaf area infected (Okamoto) was recorded periodically from the first appearance of the disease.

In all experiments two treatments were given, one at the first appearance of the blast lesions and the next about four to six days later, depending upon on the severity of the onset of the disease. The treatments were applied to eight rows of plants flanked on either side by three untreated rows, which provided a

steady source of inoculum. The dusts were applied vigorously with a small hand duster at the rate of thirty pounds per acre. Fungicidal drift was avoided by using hardboard shields. The wet treatments were applied at the rate of about 120 gallons per acre. A typical result is presented in Table 1.

Results

From this it can be seen that blasticydin 'S' at dosages of 40 ppm and 80 ppm do not show marked differences in efficacy. The lowest dosage of blasticydin 'S' is too ineffective for consideration. The dosage range of blastmycin was too low in this particular experiment for evaluation. Antimycin at dosages of 500 ppm gave very promising control. Blasticydin 'S' at 40 ppm and 80 ppm, antimycin at 500 ppm and PMA dust (containing 0.25% metallic mercury) showed approximately the same efficacy while E.C.L and E.M.P. (containing 0.25% metallic mercury) were inferior. Attention should be drawn to the fact that F.D.D.C. and copper appear comparatively ineffective under epiphytotic conditions when compared with P.M.A. and blasticydin 'S'. The use of P.M.A. on the indicas has to be ruled out owing to its excessive phytotoxicity so that at present blasticydin 'S' appears to be the most promising fungicide discovered.

An important feature was the shorter duration of the efficacy of the antibiotics when compared with P.M.A. dust. In this experiment, the effect of the antibiotics wore off after the 12th day while P.M.A. dust offered protection against blast for 4 to 5 days longer.

Phytotoxicity of Blasticydin 'S'

One hundred F.A.O. seed stock varieties of indicas were grown in cement pots and treated twice when 4 weeks old with blasticydin 'S' at dosages of 40 ppm and 60 ppm. The toxic symptoms that were observed 8 days after the last treatment were very mild and not all varieties showed them. Generally, the higher dosage of blasticydin 'S' slightly accelerated the symptoms seen. The predominant one was the formation of a faint mottling chiefly on the younger leaves. In only one variety (CH 47) did cream coloured chlorophyl free patches appear, which are characteristic of the toxic manifestations on the japonicas, and even these were slight. The following is the summary of the results:-

	Blasticydin 'S'	
Type of Symptom	40 ppm	60 ppm
1. No toxic symptoms	74	64
2. Pale green mottle faintly visible	20	30
3. Mottling clearly visible	5	5
4. Cream coloured spots	1	1
Total	100	100

A number of tests with 64 indica varieties selected from local and foreign seed stocks showed no symptoms of leaf toxicity to blasticydin 'S' at dosages of 40 ppm and 60 ppm when sprayed at "end of tillering", "early booting", and "heading" stages.

Discussion

It is apparent that for short periods the efficacy of blasticydin 'S' approximates closely to P.M.A. dust containing 0.25% mercury. However, though its durability is rather short it may be possible to increase it by combining blasticydin 'S' with a suitable phenyl mercuric compound. Owing to its potency at much lower dilutions than antimycin (40 ppm as against 500 ppm) it should prove more economical. Furthermore antimycin has been reported highly toxic to fish life in Japan, hence its use will be restricted.

TABLE 1

RELATIVE EFFICACY OF MERCURIALS AND ANTIBIOTICS FOR CONTROLLING BLAST ON UPLAND NURSERIES

FUNGICIDES	Dosage	LOCATION ONE						LOCATION TWO					
		PERCENTAGE LEAF AREA INFECTED OR DESTROYED ON											
		1st day	4th day	7th day	10th day	12th day	17th day	1st day	4th day	7th day	10th day	12th day	17th day
Basticydin 'S' Wettable	20 ppm	0.5	8.0	19.0	30.0	50.0	64.0	0.1	1.4	6.0	19.0	36.0	82.0
Blasticydin 'S' Wettable	40 ppm	0.5	2.0	2.4	4.8	24.0	44.0	0.1	0.3	0.1	3.2	11.4	84.0
Blasticydin 'S' Wettable	80 ppm	0.8	6.4	6.0	3.2	11.0	66.0	0.1	0.5	1.4	1.4	12.0	44.0
Blastmycin Wettable	50 ppm	0.4	12.0	20.0	50.0	85.0	84.0	0.1	3.6	36.0	68.0	76.0	100.0
Blastmycin Wettable	100 ppm	0.4	14.0	46.0	80.0	100.0	100.0	0.1	2.0	30.0	57.0	76.0	100.0
Antimycin Wettable	250 ppm	0.5	20.0	15.0	38.0	56.0	90.0	0.1	0.5	8.0	21.0	38.0	72.0
Antimycin Wettable	500 ppm	0.5	14.0	8.0	15.0	52.5	80.0	0.1	0.5	1.1	1.6	10.0	66.0
P.M.A. Dust	0.25%Hg	0.5	4.8	3.2	1.6	2.0	17.0	0.1	1.6	0.6	0.8	2.0	21.0
E.M.P. Dust	0.25%Hg	0.4	13.0	20.0	48.0	68.0	68.0	0.1	0.7	1.4	6.0	38.0	56.0
E.C.L. Dust	0.25%Hg	0.4	9.0	19.0	44.0	84.0	86.0	0.1	1.6	8.0	21.0	42.0	78.0
F.C. Wettable	0.12%	0.5	9.0	38.0	74.0	100.0	100.0	0.1	1.0	2.4	11.0	38.0	84.0
Control	—	0.5	12.0	29.0	74.0	100.0	100.0	0.1	0.5	9.4	40.0	60.0	96.0

Note Two treatments were given on the 1st day and 5th day fromthe first appearance of infection

There are three noteworthy points regarding the phytotoxicity of blasticydin 'S'.

(a) There is a marked varietal reaction and the indica varieties in general are much more resistant to its toxic effects than the japonicas.

(b) In the indicas the young seedlings and newly emerged leaves are usually affected, and when they are the effects are mild.

(c) Mature plants treated at late tillering or thereafter are unaffected by blasticydin 'S'.

Thus, judging from its performance, blasticydin 'S' has shown outstanding promise amongst the fungicides tested for controlling blast in Ceylon. Should its mammalian toxicity prove low, it would be preferable to mercurial formulations, for not only are mercurial fungicides a health hazard but also in a country where rice straw is used extensively for fodder all forms of poisonous contamination should be avoided.

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WHITE ROOT DISEASE OF Hevea brasiliensis: THE ROLE OF FUNGICIDES IN CONTROL TECHNIQUES

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Fomes lignosus, recorded at the time as F. semitostus, was first found attacking Hevea rubber by Ridley (1904), who suggested treating soil in an infected area with lime and copper sulphate. Petch (1921) noted that lime was generally applied to the soil after removing diseased material and he also advocated its use. Napper (1932) also thought that mycelium in the soil was potentially dangerous and recommended drenching the soil with a solution of 2% copper sulphate in addition to digging and exposing it to the sterilizing action of the sun. Riggenbach (1958) recommends, as a prophylactic measure, drenching planting points three to four times in the first year after planting and drenching the soil round a treated tree; for these uses he advocates an organo-mercury fungicide.

For treating diseased trees after the sources of infection had been removed, Petch (1921) notes that it was usual in Ceylon to dress roots, from which the mycelium had been scraped, with brunolinum or tar; he also records that Bordeaux paste was used for the same purpose in the Straits Settlements. Napper (1932) recommended that trees with roots bearing superficial mycelium only should have their roots gently rubbed with a solution of 2% copper sulphate; he records that lime-sulphur (as 1% poly-sulphide sulphur) had been successfully used for the same purpose. Later, the same author (Napper 1938) advised excision of diseased roots, removal of superficial fungal growth from unpenetrated portions of the roots, finally applying 2% copper sulphate. F. lignosus will grow over a root, not subjected to leaching, that has been washed with 2% copper sulphate, and, after serial transfers through increasing concentration, it will grow in malt-extract agar containing 1% of this chemical. The Rubber Research Institute of Malaya now recommends that tar acid fungicides should be used in place of copper sulphate and the advised treatment has also been much modified (Anon 1958).

There is sufficient evidence in the literature, for example, Bancroft (1912), Petch (1921), de Jong (1933), Altson (1953), suggesting that to control F. lignosus, diseased material of more than two or three cubic inches only need be eradicated. After excision of diseased wood, application of a fungicide should not be necessary even if the network of epiphytic rhizomorphs is left in place. In 1954, at the R.R.I.M. Experiment Station, we treated a few trees in accordance with this thesis. Penetrated portions of the lateral roots were cut off, but the epiphytic rhizomorphs were not removed and no fungicidal treatment was given. The roots healed. Since then we have observed many cases of spontaneous recovery after natural infection, as did de Jong (1933). It does not appear that those who advocated soil or tree treatment with a fungicide as an additional treatment based their advice on controlled experiments.

There are three reasons for continuing to advise the use of fungicides in a situation where we do not believe they are required. First, the harmless nature of detached or superficial rhizomorphs and small pieces of infected root has not yet been demonstrated by adequate field experiments. It has not been easy to site such experiments, though sites have now been found. Second, the success or not of disease treatment depends on the reliability of the individuals in the pest gang. Many are enthusiasts to whom saving infected trees is a matter of importance and pride. The change from collar inspection to foliage inspection (Anon 1958) means that few of the trees found to be infected can be saved. A further change, from a treatment that was meticulous to something that will appear rough and ready, must be made gradually if meticulousness is not to be replaced by carelessness. Third, if we now omit all fungicidal treatment (making only a trifling saving in the cost of control) we may later find it difficult to reintroduce the use of fungicides should they be found desirable.

Napper's scheme of periodic tree-to-tree collar inspection, followed by treatment and eradication of disease sources, was successful. Periodic foliage inspection with isolation of disease sources gives a better result; it also requires less labour, which accounts for most of the cost of control. This is particularly desirable, as wages tend always to increase; moreover the scale of new planting and replanting on many estates is such that sufficient trained labour is not available.

The disease arises from infected stumps, roots, and timber. Chemical eradication of a fungus permeating timber is obviously not feasible. Much of it is buried, its presence being known only when the disease develops on the young stand. Moreover, as many potential disease sources never become actual sources, money spent on treating them would be wasted.

Biological eradication, by the natural succession from parasites to saprophytes, is encouraged by the use of cover plants in the inter-rows. Beneath a good growth of leguminous creepers the inoculum potential of F. lignosus will be reduced to a very low level in from four to seven years. Altson (1950) noted that over 90% of the cases of F. lignosus occur within the first five years from planting. One possible solution to the root disease problem - leaving land fallow for about five years - is precluded on economic grounds. However, little disease appears in the young stand for the first two years from planting. This delay has two components; first, the time taken by the roots to make contact with sources of infection; second, the time taken by the rhizomorphs to reach the collars of the trees. Some degree of infection of the trees cannot be prevented before biological eradication is complete, but control will be obtained by measures that prevent the disease from becoming established on the young stand during the critical period from the second to the fifth year after planting.

Transmission of the disease from tree to tree is mostly by root contact. The advancing rhizomorphs will therefore usually pass the collar of each tree, growing outwards along the lateral roots of one until contact is made with a root of another tree, then inwards towards its collar, and so on. The collar is thus an obvious point at which to try to hinder the spread of disease along the planting rows.

The bark of the collar, unlike that of the lateral roots, is heavily fissured just above and below ground level. In free draining soils the cracking extends to lower levels. Field observations and those of John (1958) show this bark to be more susceptible to penetration than that of a lateral root. The collar of a tree may be

deeply penetrated by the fungus whilst several feet of the lateral root along which it travelled bears only epiphytic growth. Treatment of an infected tree is simple if excision can be limited to the lateral roots. Adventitious roots arising from the stubs of those excised soon compensate for their loss. If, however, infection has reached the collar and tap root, expensive surgery is involved if all diseased tissue is to be cut out; if it is at all extensive, the tree is condemned. Sometimes a tree may be left so weakened by excision that it is eventually thinned out as a runt or it may be blown over. Protection of the collar is thus most desirable.

Although F. lignosus when uncontrolled can wreak havoc in a plantation, yet it is really a weak parasite requiring massive inocula to establish self-propagating infections. If the inoculum potential is too slight, either by virtue of the small size of the inoculum or its age, the infected area may be cut off by wound barriers and healed over by callus formation. These two effects are well illustrated by John (1958). Examining the distribution of diseased tissue within roots shows that the rate of spread is primarily affected by the rate of spread of the rhizomorphs, not by growth within the root. Since wound barriers are sometimes successful their usual failure to prevent extension of the disease is to be attributed to the 'out-flanking action' of the advancing rhizomorphs.

If a fungicidal or fungistatic compound could be found to inhibit rhizomorph growth at the collar, wound barrier formation might prevent extension from within a lateral root into the tap root, thereby protecting the most vulnerable part of the root system and also preventing the disease from becoming established in the planting rows. The longer the duration of this inhibition, the less the danger of disease establishment, for the pathogen meanwhile is using up its food reserves and becoming weakened by biological competition.

The above arguments suggest three possible uses for fungicides. First, for general prophylactic treatment, from the second to the fifth year after planting, applied as a drench to the soil round the collars of young trees, in much the same way as we advise the use of aldrin in the control of termites (Anon 1955). In 1956, John initiated an experiment that confirmed the deduction that the rate of internal spread was dependent on that of the external growth and showed that halting the epiphytic growth of the fungus halts, for all practical purposes, its extension within the root (John 1958). We do not know, however, of any fungicide that will meet the exacting requirements of ease of application and low cost in relation to persistence. In this matter we await the outcome of enquiries addressed to manufacturers of fungicides.

The second use that is foreseen is related to the first and concerns prophylaxis in a more limited sphere, i.e., treatment at the collar of trees neighbouring those found diseased. Infection of the young stand occurs where the disease is active on the remains of the old stand and, where one case occurs, others may be anticipated. The requirements here are less exacting than before. To give protection to these trees a less persistent fungicide, applied at shorter intervals after digging the soil away from the collar, may be economic.

The third role is for treatment of diseased tissue. It is possible that suitable fungicides can be found among those now in common use to obviate the need for expensive tree surgery. If diseased tissue at the collar can successfully be treated with a fungicide, there will be a twofold gain: first, by saving labour costs (it is not unusual for a labourer to spend half a working day excising diseased tissue); second, a tree healed without excision will be much stronger than one that has been cut into.

Indeed, it will be nearly as strong as a healthy tree for the treated tissue will act as a foundation over which callus tissue will grow. For this purpose the need is for fungicides capable of penetrating diseased tissue. Latex and gel carriers, which will provide a reservoir from which the fungicide can diffuse, are being tested in addition to ordinary solutions. Specially chosen carrier formulations, by preventing run-off on to healthy tissue below the site of application, may allow the use of fungicides having some degree of phytotoxicity, provided the compounds used are not translocated.

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VOLATILE FUNGICIDES AND THEIR POSSIBLE USE IN CROP PROTECTION

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When the use of fungicides in crop protection is mentioned one usually thinks immediately of chemicals sprayed on to a growing crop — Bordeaux mixture to control potato blight, for example. During the past 15-20 years there have been great advances in the development and use of a wide range of organic chemicals for use as crop protectants and one such compound which has proved very successful for field use is captan (N-trichloromethyl-thio-tetrahydrophthalimide), first introduced in 1952. Other useful protectants have found their place in crop protection, though none is free from phytotoxicity.

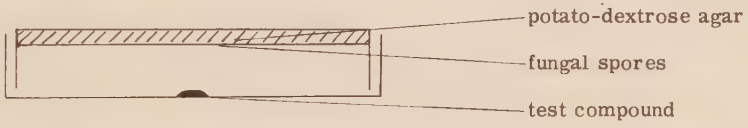
There has been progress in the use of chemicals for the eradication of certain fungal diseases. Sulphur, of course, has long been used in this way against powdery mildews; more recently a number of organo-mercury derivatives have been found to possess eradicant properties against certain fungal pathogens. These chemicals are absorbed to some extent by the leaves and kill fungi within the tissues; they thus have a type of therapeutic action. The term chemotherapy, however, is usually restricted to such compounds which are systemically distributed. These could be active within the tissues per se or they could alter the host metabolism and so indirectly interfere with the development of the pathogen. Ideally these would also protect new growth and control root rots and wilts, each

of which is beyond the scope of conventional protectants. Whilst such versatile materials are still awaited, research in this field is being actively pursued. Furthermore, promising materials have been found amongst which are certain antibiotics active against fungi.

One aspect of plant disease control with chemicals appears to have had little attention; that is the use of volatile fungicides. There are of course a number of soil fumigants which are used against soil-borne pathogens; formaldehyde, for example, comes to mind at once as having been a standard soil sterilization material for years. Most of the compounds used, carbon disulphide, coal tar antiseptics (e.g. cresylic acid), halogenated hydrocarbons (1:2-dichloro-propane, 1:3-dichloropropene, the D-D soil fumigant), vapam (sodium methyl dithiocarbamate), and methyl bromide are used as nematocides and insecticides, but some were originally tried as soil fungicides because they happened to be available or were being used for an entirely different purpose.

It is intended in this paper to consider the use of volatile fungicides on the crop above ground. There are obvious advantages in using a fungicidal vapour in such enclosed spaces as glassshouses or fruit stores; thus, application of the chemical would be easily carried out and only small quantities would be required. Furthermore, in the vapour phase there would be complete and effective contact with every part of the plant above soil level. In spite of the attractiveness of this method of control, little research has been carried out along these lines though isolated examples of fungicidal control by volatile compounds are available, such as the use of benzene and p-dichlorbenzene against tobacco blue mould.

In 1954 we began at Wye to examine the fungicidal activity of a number of compounds in the vapour phase and to do this we evolved a simple technique:



Here, a small amount of the chemical under test is placed at the centre of the lid of an inverted Petri dish. The potato-dextrose agar having been previously seeded uniformly with the spores of Penicillium italicum or Botrytis cinerea it could easily be seen, after incubation, whether the compound had any fungistatic activity in the vapour phase.

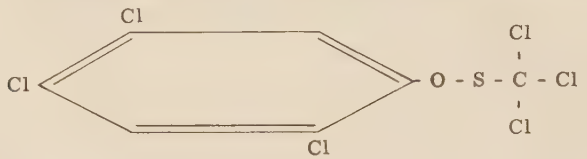
By this means the following well known chemicals among others, were found seriously to affect both fungi: thymol, camphor, chloral hydrate, naphthalene, diphenyl and chlorothymol. Other compounds failed to affect one or both of the test organisms and among them were these well known materials, dinitro ortho cresol, 2:4-dinitrophenol, tetrachlorobenzoquinone (chloranil), β-naphthol, and 2,3-dichloro-1:4-naphthoquinone (dichlone).

In view of the success of captan and the work we were doing at the time on the aryloxy acids, Professor Wain decided that it would be interesting to synthesise a series of compounds related both to captan and to the aryloxy acids of the type

Accordingly, Dr. C. H. Fawcett made a series of 30 such compounds, all, like captan, having the trichloromethylthio group. (Fawcett, Spencer and Wain 1958). During the general testing of these compounds for fungicidal activity they were included in the fumigant test, using Aspergillus niger as the test organism. It will not be necessary to list the compounds here because apart from preliminary screening the majority of them were not tested as fumigants. However, some of them showed such marked fumigant activity that it was decided to investigate them further.

To examine the activity of these compounds in a host-parasite relationship a method was devised in which lettuce seedlings inoculated with Bremia lactucae were grown in a closed container, together with measured amounts of each chemical, on filter paper, at a known distance from the seedlings. This test allowed wholesale elimination because most of the compounds were phytotoxic at a non-fungitoxic level. There finally remained, of the original 30, only four compounds which gave promising results. Two of these were abondoned because their activity was considered too low and a third was rejected because there was too fine a balance between fungitoxicity and phytotoxicity.

The one compound remaining for examination as a volatile fungicide therefore was (2:4:5-trichlorophenoxythio) trichloromethane.



[251]

In planning further work with this material as a volatile fungicide it was decided to study its effect in reducing storage rots of apples. This work was carried out in collaboration with Dr. E. H. Wilkinson of the Wye College Department of Horticulture.

In recent years the losses in stored apples caused by Gloeosporium spp. have become increasingly important (Wilkinson 1954) and it has been shown (Marsh & Edney 1956, Montgomery 1956) that losses might be reduced if the fruits to be stored are harvested only from young trees growing on heavy soil and receiving low applications of nitrogenous manures. Losses might also be reduced if applications of organic fungicides are made in July, August, and September in addition to those normally used for scab control. Complete control could only be obtained if all the sources of spore production in the orchard were removed or if the infection of the fruit by the spores normally present on their surface were prevented.

It was for this latter purpose that (2:4:5-trichlorophenoxythio) trichloromethane, compound No. 251, was subsequently used, and in early experiments Cox's Orange Pippin were stored in partially sealed cardboard boxes, together with various levels of the chemical. The control of lenticel rotting was so encouraging that it was decided to continue experiments in a more commercial fashion.

Experimental Cox's Orange Pippin apples were obtained from 23-year old trees on M IX rootstocks and to ensure a high incidence of infection they were immersed in a suspension of the spores of G. perennans, and some 70 fruits were placed in a single layer in each of 18 fruit trays. Two sets of 9 trays were stacked vertically within polythene tents to be placed in the cold store at 39°F.

For the application of the compound, apple-box liners were impregnated with the material and fixed to the underside of the three middle trays only in one stack, so that some information might be obtained on the effect of upward and downward movement of the vapour. The material in solution in acetone was sprayed on to the three box-liners so that the total amount of chemical was equal to 1 gm. per 10 cubic feet of air space inside the tent which measured 5 ft. × 2 ft. × 2 ft.

The first experiment ended in February 1958 after 17 weeks storage when the amount of rotting was assessed by (a) the number of fruits with Gloeosporium lesions and (b) the number of Gloeosporium lesions on infected fruits.

The results presented in Table 1 show that Gloeosporium rotting of Cox in cold storage was reduced in the tent containing compound 251. Of the untreated fruits only 25% were free of lesions, whereas throughout the 9 treated trays 42.3% had no Gloeosporium lesions and, in particular, of the fruits which had the impregnated box liners immediately above them, 60.2% were free of lesions. There was an average of 3.4 lesions per fruit in controls, 1.5 lesions per fruit throughout the treated trays, and in those trays with chemical above only 0.63 lesions per fruit.

TABLE 1

Rotting of Cox's Orange Pippin in cold storage caused by Gloeosporium spp.

CONTROL			TREATED		
Tray No.	Percentage of fruits with lesions[1]	No. of lesions per fruit[2]	Tray No.	Percentage of fruits with lesions[1]	No. of lesions per fruit[2]
1	76.0	3.0	1	61.8	1.6
2	78.8	3.0	2	69.7	2.2
3	69.7	3.1	3	62.0	1.7
4	87.4	6.6	4*	71.8	2.2
5	75.8	3.0	5*	40.1	0.7
6	71.7	2.6	6*	39.0	0.6
7	62.5	1.4	7	40.4	0.6
8	75.2	3.7	8	70.3	2.0
9	79.6	4.1	9	64.8	1.7
Means	75.0	3.4	Means	57.7	1.5

[1]Mean of 9 independent assessments
[2]Mean of 3 independent assessments
*Impregnated liners fixed beneath these trays

It should be noted that the overall infection in this experiment was excessive because of the artifical inoculation prior to storage.

More extensive studies were carried out with 251 in the following season (Spencer and Wilkinson 1960) when Cox's Orange Pippin were again harvested from the same trees as in the previous year. The storage space available to us was limited and so, to make the best use of it, each treatment, consisting of a unit of 8 trays with a total of some 520 fruits was again housed in a polythene tent. This time the fruits in alternate trays had been dipped in a spore suspension of G. perennans; those in the intervening trays contained apples as picked from the orchard. The same amount of chemical as used in the previous trial (0.1 gm. per cubic foot = 2 gm. per tent) was employed, but this time, instead of being concentrated on liners between the middle three trays, it was distributed over 8 liners, one of which was stapled above each tray. One tent with its 8 trays was used for each of the following treatments.

1. Controls. Box liners received acetone only.
2. Box liners bearing the chemical inserted after 6 weeks' storage
3. Box liners bearing the chemical removed after 6 weeks' storage and replaced with freshly treated liners.
4. Treated liners removed after 1 week.
5. Treated liners removed after 1 month.
6. Treated liners removed after 2 months.
7. Treated liners left in position for the duration of the experiment ($4\frac{1}{2}$ months).

Two additional tiers of trays were placed in the store not enclosed in polythene tents and one only of these was supplied with treated liners.

At the end of 18 weeks storage nine people each made a separate assessment of infection on the experimental fruits; this again involved counting the total number of Gloeosporium lesions on each infected apple. The figures in Table 2 are the means of the nine assessments.

TABLE 2

Effect of treatment with 2:4:5-(trichlorophenoxythio)trichloromethane on Gloeosporium rotting of Cox's Orange Pippin in cold storage

	INOCULATED*		UNINOCULATED	
	Percentage of fruit with lesions	Lesions per infected fruit	Percentage of fruit with lesions	Lesions per infected fruit
In polythene tents				
Control	87.0	7.6	50.2	4.6
Treated after 6 weeks storage	93.4	11.9	47.3	4.6
Liners replaced after 6 weeks	52.4	4.4	19.7	2.1
Treated 1 week	63.2	4.3	29.5	3.1
Treated 1 month	43.9	3.8	25.0	2.9
Treated 2 months	40.5	2.7	17.6	1.5
Treated $4\frac{1}{2}$ months	37.4	2.4	11.8	1.6
Not in tents				
Control	49.8	3.0	17.5	1.8
Treated	35.4	1.6	16.4	2.4

* Inoculated fruits dipped in a suspension of the spores of G. perennans before treatment. Uninoculated fruits stored as picked.

These results show that where treatment did not begin until after 6 weeks of storage there was little reduction of Gloeosporium rotting in the uninoculated apples. The corresponding apples which had been inoculated, however, showed an increase in infection. This suggests that the infection process is well advanced after 6 weeks and it would appear, therefore, that if control is to be achieved treatment should begin immediately the fruits are placed in the store.

Removal of the treated liners after 6 weeks storage and their replacement with liners freshly impregnated with the chemical somewhat surprisingly did not give as good a result as the full-time treatment; since the replacement liners had no beneficial effect, opening the tent after 6 weeks had the effect of ending the treatment.

Removal of the treated liners at various times throughout the experiment influenced the degree of Gloeosporium rotting. Thus, for example, 87% of the inoculated controls developed lesions, whereas of those treated for 1 week 63.2% did so, and of those treated for the length of the experiment only 37.4%.

The Cox's Orange Pippin used in these experiments were carrying a natural inoculum of Gloeosporium spp. which, at the end of storage, meant 50% of those untreated (i.e. the uninoculated controls) being rejected as infected. Treatment with 251 at 0.1 gm. per cubic foot of the atmosphere for only 1 week reduced this figure to less than 30% and allowing the treated box-liners to remain within the polythene tent for the length of the storage period reduced the percentage of rejected fruits to less than 12. It can be seen from the table that the number of lesions per fruit follow these general trends, thus, treatment for 1 month or 2 months gave results intermediate between those for 1 week and $4\frac{1}{2}$ months.

When it is remembered that for storage to be economical the grower can afford to lose no more than about 10 per cent of his apples a reduction in the percentage of rotted fruits as achieved in our experiments would make the difference between loss and profit in many apple stores.

The reduction of Gloeosporium attack in those trays of apples kept in the open store was much less than was achieved in the tents. This is not at all surprising since each of the treated box liners carried only the same amount of chemical as each of those used in the tents. The vapour concentration which such a relatively small amount of material could maintain would clearly be much less in the open than under the tent. The greater incidence of infection of the fruits in the polythene tents compared with that of apples in the open store can be attributed to the high humidity prevailing in the tents.

Thus, from the evidence obtained in laboratory experiments and on the basis of results obtained in two seasons it can be concluded that Gloeosporium rotting can be reduced by store fumigation using (2:4:5-trichlorophenoxythio)trichloromethane. Comparison of the results obtained in 1958 and 1959 shows that the same quantity of this chemical concentrated on three box liners and placed near to the apples gave no better results than when it was distributed uniformly throughout the chamber. These results indicate that control of Gloeosporium can be obtained by a certain minimum atmospheric concentration of the fumigant. The fact that there was little or no control of Gloeosporium in those trays kept in the open store indicates that this minimum vapour concentration was not maintained under these conditions.

Whilst compounds other than (2:4:5-trichlorophenoxythio)trichloromethane may also prove useful as volatile fungicides for this purpose, there remains the problem of finding an effective method of vapourising the chemical into the atmosphere of the store. From the present results it would appear that an effective atmospheric concentration of our compound was maintained within the polythene tents, but it should be noted that the amount of chemical used in our experiments (0.1 gm. per cubic foot of air space) was somewhat arbitrarily chosen. This amount gave promising results in earlier work and since it was possible to study only a few factors at a time this figure remained unchanged. Whether, in fact, the vapour concentration obtained from this quantity of chemical at 37°F is the optimum, is not known, but the absence of fruit damage and taint indicates that larger amounts might be tolerated. It may well be that fumigation with a high concentration for a short period would give adequate control without causing fruit damage.

In our experiments we have not studied the mammalian toxicity of this chemical, but members of the department have eaten quantities of apples used in these experiments without ill-effects, and it is understood that toxicity trials are being carried out elsewhere. It is suggested that the compound might prove useful in other situations; for example, for preventing rotting of fruits such as bananas and oranges in shipment. There are also decided possibilities for the use of volatile fungicides applied as aerosols for controlling fungal diseases on crops grown in glasshouses.

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ADAPTATION OF FUNGI TO FUNGICIDES

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It is well known that bacteria become resistant to antibiotics and other drugs, and that insects become resistant to insecticides, such as D.D.T., and that this has given rise to serious problems in medicine and applied entomology. Development of resistance by fungi to fungicides would not be surprising because of the propensity of living organisms to adapt themselves in one way or another to unfavourable environment, but what is somewhat surprising is the fact that although fungicides, particularly those based on relatively simple compounds of sulphur and copper, have been used for a very long time, in all parts of the world, against a wide variety of fungi, so far there is very little evidence that resistant strains have anywhere become important under field conditions on growing crops.

Horsfall (1956) has stated that Phytophthora infestans on the Atlantic seaboard of America may now be more difficult to control with Bordeaux mixture than it was when potato crops were first sprayed with this fungicide, but probably better evidence for resistance is that of Taylor (1953), who found that spores of Physalospora obtusa from orchards regularly sprayed with Bordeaux mixture were more resistant to copper than were spores from unsprayed orchards. Along somewhat different lines is the isolation by Littauer and Gutter (1953) of a strain of Diplodia natalensis resistant to diphenyl, a fungicide used to reduce wastage of citrus in storage and in transit, and there are also reports of resistance developing against fungicides used to prevent deterioration of manufactured products.

But, to revert to the main point, resistance to fungicides used in horticulture and agriculture has not yet become a problem, and why this is so is something of a mystery because a number of people have shown that in the laboratory it is relatively easy to obtain strains of fungi more resistant to fungicides than the wild type. Most of these strains have been obtained by a process of "training" in which the fungus is exposed to gradually increasing, but sub-lethal, doses of a particular fungicide. Eventually strains may be obtained which are able to remain alive, or grow, in higher concentrations of the fungicide than are tolerated by the parent strains. Generally, however, the "training" process is a slow one, the level of resistance obtained is not very spectacular, and growth in the higher concentrations of the fungicide is slow and abnormal. By this method Sclerotinia fructicola and Aspergillus niger have been trained to tolerate increased concentrations of copper sulphate, and Sclerotium rolfsii and S. delphinii have been adapted to sodium arsenite. Greathouse (1954) made the interesting discovery that Aspergillus niger developed resistance to copper oxinate but not to oxine, the resistant strains losing their tolerance when transferred to a fungicide-free medium. The implication here is that resistance is to the copper cation.

When one considers how these resistant strains have been produced in the laboratory and how they behave subsequently both in the presence and absence of the fungicides it is difficult to imagine how they could become important under field conditions. Quite different results have been obtained with another group of compounds, the chlorinated nitrobenzenes, and the rest of this paper will be mainly devoted to the resistance of fungi to them.

Two of these compounds have been, and still are, used commercially on a moderate scale, pentachloronitrobenzene (PCNB), and tetrachloronitrobenzene (TCNB). There are three isomers of the latter, 2,3,5,6 TCNB; 2,3,4,6 TCNB,

and 2, 3, 4, 5, TCNB, but only the 2, 3, 5, 6 isomer seems to have been used practically. PCNB and TCNB were developed by Brown and his associates at Imperial College for the control of Botrytis cinerea and Rhizoctonia solani on lettuce. One or both have since been used for the control of Botrytis spp. and Rhizoctonia solani on other crops, and for the control of Fusarium caeruleum, Tilletia caries, Plasmodiophora brassicae; and a number of other pathogens.

Resistance to these compounds was first reported by Roy (1947) for Botrytis cinerea: later, Brook and Chesters (1957) and other workers obtained similar results.

Dealing now with the resistance of Botrytis spp. to PCNB and TCNB, in the first place it must be said that the chlorinated nitrobenzenes are fungistatic rather than fungicidal, and that although they are at first very effective against some fungi, particularly Botrytis spp., they have no readily observable effect against others, e.g. Pythium spp. Also they are insoluble and do not normally prevent spore germination, although they retard it and the subsequent growth of the germ-tube. They are, however, appreciably volatile so that in appropriate concentrations of the vapour growth of fungal colonies is retarded and profoundly modified in other ways, e.g. the hyphae are mis-shapen, and sporulation is greatly reduced or inhibited.

Resistant strains are obtained in the following way. Ten mg. of PCNB, or each of the TCNB isomers, is distributed evenly over the inside surface of a lid of an inverted Petri dish, by evaporation from an acetone solution. The dish containing nutrient agar is seeded at the centre with a 5 mm. diameter disc containing non-sporulating mycelium. With Botrytis allii, macroscopically visible growth from the disc is seen after one day with PCNB, 5 days with 2, 3, 4, 5 TCNB, 8 days with 2, 3, 5, 6 TCNB, and 9 days with 2, 3, 4, 6 TCNB. The hyphae produced during the initial growth are grossly malformed.

The effect of these substances on the rate of growth of the colonies and on the morphology of the hyphae increased in the same order as that given for macroscopically visible growth. A few spores appeared in the PCNB cultures, but not in the TCNB cultures. Resistant strains began to appear in PCNB cultures after 5 days, and in 2, 3, 4, 5; 2, 3, 5, 6; and 2, 3, 4, 6 TCNB cultures after 10, 21, and 23 days. A large proportion of the cultures grown in the presence of the fungicides sooner or later produced resistant saltants, which seemed to originate at the edge of the colony at one or more points, and then rapidly to extend over the surface of the agar as a fanshaped growth, somewhat paler in colour than the parent strain. Subcultures from these resistant colonies grew almost as quickly in the presence of the fungicide as did the parent isolate without the fungicide, but only the PCNB-resistant strain sporulated under these conditions. In the absence of the fungicides, resistant and parent strains were very similar in all readily observable ways.

Resistant strains produced in response to each of the four fungicides were now grown in liquid and on solid media in the presence of each of the four fungicides to see how far resistance to one fungicide conferred resistance to another. In liquid media, results were assessed on two bases, rate of utilization of glucose, and dry weight of mycelium produced; on solid media, rates of linear growth were measured. The three methods of assessment gave similar results. In the absence of the fungicides, the four resistant isolates and the parent isolate behaved similarly. In liquid media in the presence of the fungicides the resistant strains utilized glucose more efficiently than the parent, and this was reflected in the dry weight of mycelium produced. On solid media in the presence of fungicides the linear growth rate of the resistant strains was always higher than that of the parent isolate.

There is insufficient time to deal in detail with the results obtained with cultures grown in the presence of the fungicides, but the general picture is that resistance to one of the fungicides always confers some resistance to the others, but that the extent of the resistance depends on the origin of the strain. Thus, for the two end members of the series, PCNB is the less fungistatic, and the PCNB-resistant strain is not affected by PCNB, but its growth is reduced by the others in the order 2, 3, 4, 6, > 2, 3, 5, 6, > 2, 3, 4, 5, TCNB. But it still grows better than the parent in the presence of TCNB. 2, 3, 4, 6, TCNB is the most fungistatic of the four substances and the 2, 3, 4, 6 TCNB-resistant strain is almost unaffected by the

other three fungicides. Corresponding results are obtained with the other strains.

Strains resistant to PCNB and TCNB were also tested against three isomers of dichloronitrobenzene each of which was found to be more fungistatic than PCNB and TCNB. The three isomers used were 2, 3; 2, 4; and 2, 5 dichloronitrobenzene. The order of resistance to the dichloro compounds was 2, 3, 4, 6 > 2, 3, 4, 5 = 2, 3, 5, 6 TCNB. The PCNB-resistant strain was no more resistant than the parent isolate. The 2, 3, 4, 6 TCNB-resistant strain was by far the most resistant; at 10 mg. per Petri dish this strain survived and grew slightly whereas the other strains were killed by this treatment.

The dibromo- and diiodo-compounds were not as fungistatic as the dichloro-compounds, and the PCNB- and TCNB-resistant strains were also resistant to these compounds. Two halogenated anilines were also tested; 2, 3, 5, 6 tetrachloro-aniline, prepared by reduction of 2, 4, 5, 6 TCNB, and 2, 6 dichloro-4-nitroaniline, which is the active principle of "Allisan", a fungicide recently introduced for control of Botrytis cinerea. Both compounds were fungistatic to B. allii in liquid and on solid media, but the PCNB- and TCNB- resistant strains were resistant to them.

The 2, 3, 4, 6 TCNB-resistant strain was also found to tolerate and grow in higher concentrations of benzene than did the parent strain.

Coming now to the significance and use of these resistant strains, clearly they might be used in attempts to determine the mode of action of the chlorinated nitro-benzenes because as yet little or nothing is known about this. So far, however, little progress has been made along this line. Analysis by paper chromatography of mycelial and culture filtrate extracts of parent and resistant strains grown in the presence and absence of the fungicides did not reveal any differences. Also, after the 2, 3, 5, 6 TCNB-resistant strain had grown for two months in liquid media containing 2, 3, 5, 6 TCNB, examination of mycelial and culture filtrate extracts gave no suggestion that the TCNB had been made less toxic by reduction to the less fungistatic tetrachloroaniline.

On the more practical side, in view of the rapidity with which resistant strains appear in the laboratory, and the fact that they are almost completely resistant to the fungicides, it is rather remarkable that resistance to the fungicides has not yet become a major problem, particularly when these fungicides are used in confined spaces, e. g. frames and greenhouses. In this connection it may be significant that Way & Key-worth (1959) mention that advisory officers and growers sometimes find that PCNB and 2, 3, 5, 6 TCNB do not give consistent control of Botrytis cinerea on lettuce, so it is possible that in some places this fungus has acquired resistance to these fungicides. It would be interesting to obtain isolates of B. cinerea from crops where control has been unsatisfactory to see whether or not they were resistant to 2, 6 dichloro-4-nitroaniline, the active principle of the recently introduced "Allisan".

Finally, we have found with B. allii that the 2, 3, 4, 6 isomer of TCNB is much the most fungistatic and is also the isomer to which the fungus acquires resistance least readily and most slowly. There are probably very good reasons why this isomer is not used commercially, because otherwise it would seem to be a more desirable fungicide than PCNB or 2, 3, 5, 6 TCNB. The dichloronitrobenzenes would appear to be even better fungicides, but their use is precluded because of their phytotoxicity.

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Discussion following papers by J.W.L. Peiris & G.C. Marks.

C.J. MAGEE (Australia) asked if Mr. Shanmuganathan had any idea of the costs of spraying with antibiotics.

N. SHANMUGANATHAN (Ceylon) replied that few antibiotics had as yet been tested on a field scale so no clear idea of costs could be given.

C.J. MAGEE remarked that one had been used commercially to some extent in the U.S.A. to prevent mould growth on cut ends of bananas.

I.W. CALLAN (U.K.), referring to the phytotoxicity of phenylmercuric acetate on rice, said that his own experience in British Guiana had shown that PMA applied at low volume (5-10 gal./acre) is much safer on indica varieties of rice than either PMA dusts of PMA solutions applied high volume (50 gal./acre). In terms of concentration, 250 ppm Hg applied low volume is appreciably less phytotoxic than 50 ppm Hg applied high volume, probably because low volume application gives a finer droplet and more even distribution.

M.H. MOORE (U.K.) said that several sprays are less phytotoxic at low volume than at high volume, but high Hg concentration applied at low volume may be objected to on mammalian toxicity grounds.

Discussion following paper by R.A. Fox

C.J. MAGEE asked if any attempt had been made to combat white root of Hevea by removing soil from around the tree to leave a hollow at its base.

R.A. FOX (Malaya) replied that this idea had been well known in the Far East since before the war and had been used quite extensively in the then Dutch East Indies, becoming known as the 'Dutch Method'. There were three objections to it. Firstly, it weakens the anchorage of the tree, to different degrees in different soils as they affect the development of the tap-root. Secondly, the hollows need to be cleared regularly otherwise accumulation of plant debris and silt defeats its purpose. Thirdly, stagnant water in the hollows may become breeding foci for malaria-transmitting mosquitoes.

R.W.J. BYRDE (U.K.) asked which compounds Mr. Fox envisaged using against white root rot of rubber. Presumably compounds possessing eradicant fungicidal activity would be needed such as dinitroorthocresol, pentachlorophenol, organomercurials, and organotin compounds. The phytotoxicity of these would apparently not seriously limit their use, but they are all more or less toxic to mammals.

R.A. FOX said that the list of suitable potential fungicides for this purpose is extensive and phytotoxic compounds, such as pentachlorophenol were included. He had recently received some preliminary results from Malaya of screening

trials on a range of organotin compounds. These suggest that Fomes lignosus is more sensitive, on a weight for weight basis, to tin than to mercury. He would welcome information on the mammalian toxicity of these compounds; a brief acquaintance with them had shown them to be skin irritants. In this connection, the dangers attending the use of toxic compounds in plantation crops needs strong emphasis. In temperate regions fungicides, pesticides, and herbicides are usually used only at specified periods of the year, these being dictated by life-cycles as affected by climate. The labourer applying them is only exposed to danger intermittently and precautions are both readily understood and easily enforced. In tropical plantation crops there may be permanent 'pest and disease gangs' handling control chemicals throughout the year. Before recommending the use of any compound of potential danger the following points must be borne in mind. In the tropics it is nearly impossible to wear protective clothing for any length of time. The labourer's ordinary clothing may be scanty, thereby exposing a greater area of skin to contamination. At high temperatures compounds are more readily absorbed through the skin and the increased danger from volatile compounds is self-evident. In addition, it is difficult to persuade illiterate or semi-literate labourers of the dangers of a poisonous compound the action of which is not immediately evident.

Discussion following paper by D. M. Spencer

C. J. MAGEE said that fungicidal fumigants was a field which had given interesting results in the past. In Australia, they had used volatile fungicides as seed treatments, e.g. against tobacco blue mould. He hoped that the work at Wye would eventually benefit food storage both in Britain and overseas.

R. G. TOMPKINS (U. K.) also wished the workers at Wye success in developing volatile fungicides. The search for such compounds is of long standing, for example between 1930 and 1939 the Low Temperature Research Station, Cambridge, successfully used acetaldehyde, ammonia, iodine, diphenyl and o-phenylphenol to reduce rotting of certain fruits. Of these, diphenyl has been used for many years throughout the world to reduce loss in citrus. Klotz in the U. S. A. introduced the use of nitrogen trichloride for treating citrus and this has been used on a large scale in Israel. Sulphur dioxide was being used in the U. S. A. and S. Africa in the storage and transport of grapes. During the war, volatile fungicides were used to prevent mould growth on a wide variety of supplies held under tropical conditions. Slightly volatile sprout suppressants were introduced round about 1940, and recently Burton has developed the use of nonanol for this purpose, and this is now being used commercially.

However, effective compounds are not easy to find and even if they are the Preservatives in Food regulations must be modified to permit their use. To bring this about lack of toxicity must be proved, involving the determination of the amount of fungicide taken up by the fruit. There must also be good evidence that the fungicide is effective and its use desirable on the grounds that other methods are not available. Proof of this would depend on commercial scale trials, which would themselves be contrary to the regulations if the fruit was used for consumption. Nevertheless, if promising fungicides are found it should not be too difficult to assess their value and it is sincerely hoped that some such compounds will be found in the near future.

C. J. MAGEE remarked that if the U. K. would not allow the use of some of these substances, they might be tried out in Australia. Salicyl L had been used on bananas in Australia for 25 years; they have thick skins and it is unlikely that anyone would eat the skins. In the U. S. A., however, the United Fruit Co. were advised that the Food & Drug Legislation would need 5 years to pass salicyl L. He wondered if, in applying these compounds, we were killing the fungus, rendering it static, or reinforcing the host. He had noticed that from a storage point of view the finish was often better on treated fruit, which would suggest an effect on the host.

J. DE TEMPE (Holland) asked whether 'Wye 251' had been tried on seeds; there is a need for a volatile disinfectant which can be used on stored seed prior to pre-sowing protection.

D. M. SPENCER replied that it might be useful as a disinfectant or protectant

immediately before storage. He had tried it on peas infected with Ascochyta, but the effect was not long lasting.

L. OGILVIE (U.K.) asked if treatment with 'Wye 251' impaired germination if the seed was sown immediately after treatment.

D. M. SPENCER replied that in seed selected for absence of infection germination had been as good as in the control.

MISS M. NOBLE (U.K.) said that she had tried to trace the path of Ascochyta infection in pea from the pod to the seed and had found some evidence that it passed down the funicle, through the hilum, and into the tissue beneath. This happened quite frequently compared with infection through the testa from a lesion on the pod wall, especially with A. pisi. Hence volatile fungicides might be effective in controlling this infection as they would presumably penetrate the hilum.

Discussion following paper by D. Priest & R. K. S. Wood

A. J. H. CARR (U.K.) said that the variants resistant to volatile fungicides described could have arisen by dissociation of a heterokaryon by culture on a medium favouring the growth of the resistant constituent only. The absence of resistant strains in the field following repeated fungicidal treatment, as compared with the facility with which they are obtained in the laboratory, can possibly be explained by the difference in the role played by heterokaryosis in the life cycles of different fungi. Most fungi, having uninucleate sexual and asexual spores, have no mechanism for the perpetuation of a heterokaryon other than the vegetative mycelium, which is limited in time and space. Hence, any resistant variant, which is also at a selective disadvantage in the field, will be eliminated from the population. However, where (as in Botrytis allii) the heterokaryon is perpetuated through multinucleate asexual spores, the effect of the resistant variant will be masked by the wild-type nuclei in the heterokaryon. Such a variant will be carried and perpetuated until such time as resistance to fungicide becomes the dominant selective force, when the variant will be at a selective advantage and so will dissociate from the heterokaryon. Where parasexuality occurs, genic recombination could ultimately lead to the selection of a genotype combining resistance to fungicides with other selectively advantageous characteristics. Some information on the genetic mechanism controlling these variants could be obtained by producing heterokaryons between the different variants and between each variant and a wild-type stock and culturing these on various selective media.

D. PRIEST (U.K.) said that B. allii was chosen for this work because it was pathogenic under field conditions; it was hoped that its genetics might be studied in the future.

C. L. A. LEAKEY (U.K.) thought that the observations of reduced mycelial growth in association with unchanged carbohydrate utilization strongly suggested the uncoupling of oxidative phosphorylation. Hence, respiration, expressed in terms of substrate utilization, is rendered insufficient for the formation of the A. T. P. necessary to supply the energy requirements of metabolic processes. This is the effect of some mutagenic agents, and Somantini et al. had shown that it can often be countered by adding manganese to the medium. It would seem possible that a metabolic shunt is involved.

D. PRIEST agreed that a metabolic shunt was a possibility.

J. DE TEMPE (Holland) remarked that wheat bunt provided an example of resistance developed in the field. This may be related to a morphological characteristic, namely the thickness of the slime layer around the spore.

C. J. MAGEE (Australia) said that this problem of resistance had been worrying entomologists for many years, Insects developed resistance mainly to hydrocarbon insecticides; metals were involved in a few cases, but where lead and arsenicals have been used resistant forms have not been developed.

J. DE TEMPE said that suppressed non-resistant insect forms usually recover in number when the particular insecticide is withdrawn. The duration of generations

might determine the speed of recovery. With most fungi the generations are so short and multiplication so strong that a resistant strain might not show up at all. Wheat bunt, with one generation per year, is an exception.

I. W. CALLAN (U. K.) thought that the idea of resistance should be kept in its true perspective. In the case of wheat bunt, some strains of Tilletia have been shown to have 2 or 3 times the resistance to organo-mercurials compared with normal strains, and others with resistances in the order of 5 - 10 times the normal have been reported Resistance in insects is of quite a different order; DDT-resistant house flies, dieldrin-resistant mosquitoes, and phosphorus-resistant red spiders are able to tolerate several hundred times the concentrations of insecticide that would kill non-resistant strains. He knew of no case where resistance in fungi approached this magnitude.

R. K. S. WOOD (U. K.) replied that this was not quite true. It was not known how these compounds acted and so one cannot think in terms of concentrations. The growth of the strains discussed in this paper was unaffected by an atmosphere saturated with fungicide, indicating almost complete resistance.

N. SHANMUGANATHAN (Ceylon) asked how well these variants retained their resistance through successive subcultures.

D. PRIEST replied that once a resistant strain had been obtained by mycelial culture it retained its resistance through a considerable number of subcultures. The level of resistance is maintained even when the fungus is subcultured in the absence of the fungicide.

R. K. S. WOOD added that it was easy to obtain strains which grow vegetatively in the presence of fungicide. but sporulating strains are more difficult to find.

July 21 morning

Virus diseases and cereal rusts

Chairman: Dr. B. L. Chona

THE RELATION BETWEEN AIR TEMPERATURE AND THE OCCURRENCE OF SYMPTOMS OF PHLOEM NECROSIS VIRUS DISEASE

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Summary

(1). Phloem necrosis is a virus disease of the tea bush reported only from Ceylon, with a wide range of symptoms eventually stopping the production of new shoots.

(2). In Ceylon the disease is rarely found except in the up country (over 4,000 ft. above mean sea level) and is severe in the highest parts of the up country (over 5,500 ft.).

(3). When diseased material from 6,000 ft. is taken down to the low country, the plants show a complete recovery and no symptoms of the disease develop on the new growth. When these treated plants are transferred back to their original location, a retardation in growth results, but no evidence of a recurrence of the disease has been observed as yet. The indications are that the effect might be of long duration, if not permanent.

(4). When diseased material is subjected to high temperatures artificially, a complete absence of symptoms on the new growth results. This effect may be only temporary, as the symptoms may reappear on treated bushes, which are kept at

normal temperatures after treatment. The untreated controls showed no change in the symptom expression.

Introduction

Phloem necrosis is a little-known virus disease in tea. We have, at present, no clear picture of its taxonomic, physiological, and ecological aspects. A short general introduction about the disease itself may therefore be welcomed before talking about the relation between air temperature and the occurrence of symptoms.

The disease is found only in Ceylon and there, too, only in the up-country tea districts. It was shown to be caused by a virus by grafting experiments carried out by Gadd (1939 a, b) at the Tea Research Institute of Ceylon, and confirmed by Bond (1944 a, b).

It is characterised by one or more of the following symptoms:

(1) A gradual decline occurs in the general condition of the diseased bush which becomes stunted and non-productive.

(2) There is often a backward curling of the leaves, accompanied by zig-zagging of stems, which have shortened internodes.

(3) Sometimes, diseased bushes exhibit an upward twisting of the leaves instead of a backward curling. This symptom is rather rare, and was only very recently known to be associated with phloem necrosis virus disease.

(4) Premature flowering, fruiting, and seed production are profuse.

(5) There is a considerable reduction in leaf size resulting in severe losses of crop.

(6) The leaves tend to be arranged in one plane on the stems rather than be disposed all round the stems as on healthy bushes.

(7) The foregoing symptoms are not strictly diagnostic of the disease. Some of these symptoms can be caused by factors other than the virus itself. The real diagnostic character however, is the presence, in all cases, of a characteristic type of necrosis of the phloem tissue in the roots, stems, petioles, and leaf midribs.

It has been observed that the small-leaved varieties of tea (the so-called low-jat or China types) are very sensitive to the disease, producing clear symptoms, while the larger-leaved varieties (known as the high-jat or Assam types) appear to be tolerant (symptomless carriers), exhibiting none of the typical symptoms associated with the disease. In all our experiments we have used only the susceptible low-jat material.

Distribution of the disease

Recently, we conducted a survey of the distribution of phloem necrosis virus disease in Ceylon. This revealed that the symptoms are most marked and the deterioration of the bushes most rapid at the highest elevations (i. e. between 5,000 and 7,500 ft. above sea level). The appearance of symptoms on bushes in areas between 4,000 and 4,500 ft. is not very common, while, so far, it is unknown below 4,000 ft. In one planting district, situated almost entirely above 6,000 ft., the disease has been recorded from every estate.

There is a steady increase in the severity of infection with increase in elevation. Only an occasional diseased bush here and there could be found in fields planted with low-jat teas at about 4,500 ft. whereas in areas over 6,000 ft., infection in bad fields can be as high as 60-70% of the bushes, while as many as 10-15% of them may be completely unproductive.

Our knowledge of the mode and rate of spread of the disease is extremely scanty, yet we do know that the deterioration of infected bushes is a remarkably slow process.

No insect vector is yet known. The study of the distribution of the disease indicates that elevation plays an important part. Is this because of climatic conditions affecting the virus itself? Or is it because climate controls the spread of the disease by its influence on the distribution of the possible insect vector? Or is it because climate controls the reaction of the plant on the presence of the virus (masking)?

It has been known for some time that vegetative propagation of diseased material gives rise to diseased plants. Diseased material selected from one estate situated at 6,000 ft. was taken down to sea level and planted in an isolated area in a clonal-proving station of the Institute.

The diseased material consisted of (1) cuttings (propagated at sea level); (2) cuttings (propagated at the Institute, 4,500 ft. and later taken down to sea level); (3) root suckers taken from diseased bushes, and (4) whole diseased bushes.

The diseased material was kept in the low country for varying periods. On an average, about 6 months after being taken down to sea level, the diseased material showed no symptoms on the new growth. Admittedly the rooting percentages of the diseased cuttings were not so high as the figures for healthy material, but still, the cuttings that survived were completely healthy. The diseased bushes and root suckers showed no symptoms on the new growth, which was luxuriant.

A part of this material was taken back to the up-country estate at 6,000 ft. above sea level. The result was an immediate set-back in growth, as is to be expected from any such change. The majority of plants did not produce any new growth for periods ranging from 3 to 6 weeks, while about 14% of the young plants produced no new growth even after 6 months. At the end of the 6-month period the plants were examined for symptoms of the disease. Seventy six per cent of the young plants showed healthy normal growth, while 8% caused suspicion, but could not definitely be identified as having symptoms of phloem necrosis virus disease. Twelve per cent of the plants were stunted with small leaves. (This condition is common in tea especially after pruning, and is referred to as "little leaf"). However, microscopic examination of the phloem revealed no signs of necrosis. These results show that the plants can lose the symptoms of the disease, and the experiments give an indication that the change is possibly permanent.

From these experiments we know at least that high temperatures suppres the symptoms of the disease but whether high temperature leads to a complete cure cannot be concluded until a longer period has elapsed. In another experiment we attempted to investigate which particular range of temperature was critical in controlling the expression of the disease. Two thermographs have been installed at 6,200 and 4,200 ft. elevations at one estate, the slope of which is extremely steep. At the higher elevation, the tea is heavily necrotic, while at the lower only occasional bushes are observed showing very mild symptoms. We assumed that 4,200 ft. could, within reasonable limits be considered as a marginal area, where the disease is not very widespread or severe. Diseased bushes from the highest part of the estate were transplanted to 4,200 ft. The bushes have been slow in recovery from transplanting but still show a partial reduction in the severity of the symptoms. We can therefore assume that the marginal area, where the critical temperature effect comes into play, may be less than 4,200 ft. in elevation at this estate. (We know of course that what is important is the temperature, and not the elevation, and hence we specify 4,200 ft. at this particular estate). We can therefore draw the following conclusions:

(1) That the difference of temperatures observed between 6,200 ft. and 4,200 ft. at this estate is sufficient to cause a clear reduction in the severity of symptoms of phloem necrosis virus disease.

(2) That the symptoms have definitely not been completely suppressed at 4,200 ft., and are liable to manifest themselves more strongly if the bushes are taken back to 6,200 ft.

(3) That 4,200 ft. at this estate is not the lowest elevation where phloem necrosis can occur. It probably occurs lower down, though symptoms in the field are rather obscure.

In the laboratory , a thermostatically controlled constant temperature room was constructed, where the temperature was maintained at about 80° to 85° F continuously both day and hight. The necrotic bushes from 6,400 ft. were placed in this room and showed a complete recovery after 4 months of treatment, while diseased bushes standing outside the hot room remained diseased. There was excellent growth, and the size of the leaf increased to more than three times the original size.

The following conclusions can be drawn regarding this experiment:

(1) That since conditions of illumination were approximately identical for the plants inside the hot room and outside it, the question of the differences in the quality and quantity of illumination does not arise in connection with the appearance of symptoms of phloem necrosis virus disease.

(2) The plants which were in the hot room did not show a trace of symptoms on the new growth, indicating that the high temperature has definitely suppressed the symptoms.

Phloem necrosis virus disease is present on the higher fields of the Institute's estate, nearly 5,000 ft. in elevation. A few of these bushes were brought down to 4,500 ft. in 1939, and have so far remained necrotic, indicating that the disease has not been cured by the slightly higher temperature present in the area 500 ft. below the original. Also, bushes brought down from an estate 6,400 ft. in elevation to 4,500 ft. remain necrotic.

It is clear that in all these experiments, although there was a complete disappearance of symptoms, it is not definite whether the cure is a permanent one. Indeed, it is possible that the masking of symptoms is only temporary, and that if sufficient time elapses at lower temperatures the symptoms would reappear.

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TRISTEZA DISEASE IN CEYLON AFFECTING ORANGE SEEDLINGS

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Diseases of citrus in Ceylon came into prominence about the year 1956 in the Bibile area where considerable cultivation existed. The citrus in this area, mainly sweet orange, has flourished for 20 - 30 years in tracts of cleared jungle. Reports at this time of chlorosis, die-back etc. were investigated and although the usual control measures for the commonly occurring fungal diseases like pink disease (Corticium salmonicolor) and mildew (Oidium tingitaninum) were carried out, not much impression was made in arresting the die-back. It was, however, observed that the disease was most severe in holdings where citrus was poorly cultivated and manured and where the soil fertility was low. In as much as these citrus plantations were almost totally planted with seedling sweet orange, the possibility of a virus of the tristeza type being the casual agent appeared rather remote. A general survey of citrus throughout the island showed that the decline was not only confined to the Bibile area but was found in various parts of the

island, and even very young seedlings 2 - 3 years old were affected.

Grafted sweet orange plants were at the time produced in Government farms using as scion a local seedless orange variety - Bibile seedless on sweet orange stocks. Observations on nurseries brought out the fact that a considerable number of these scions showed poor growth and yellowing of leaves reminiscent of the decline of sweet orange on sour orange stocks reported in other countries. Budding experiments were initiated using as scions buds from apparently healthy and declining sweet orange from Bibile and grafting them on sweet orange and rough lemon stocks in the field. The indications at the end of the six months were that the buds from declining orange when budded on sweet orange stock showed dwarfing of scion growth and a bronzed yellow colour of leaves which became chlorotic in time. The healthy scions were normal in growth with a green, healthy flush and the scion growth was three to four times that of scions from declining trees. On rough lemon, both diseased and healthy sweet orange showed a slightly better growth than buds taken from diseased plants. (Peiris & Bertus, 1958).

Tests for starch distribution by the iodine test in the two sets of grafts made with diseased and healthy scions on sweet orange stock showed depletion of starch below the bud union in the former with obvious signs of phloem necrosis at the bud union. Grafts made with apparently healthy scions on sweet orange and both type of grafts made on rough lemon did not show these symptoms. It is known that rough lemon stocks are more tolerant of the tristeza virus and decline on the stock is much delayed.

The decline of sweet orange scions on sweet orange stocks was, if not unique, at least an interesting phenomenon. Kiely (1957) postulated that if sweet orange can decline on sweet orange stocks as a result of tristeza infection there was a prima facie case to consider that the decline of sweet orange seedlings on their own roots was also due to a virus.

Transmission to Lime Seedlings

Transmission experiments were, however, necessary to establish the presence of a virus in declining sweet orange. These were subsequently carried out using the citrus aphid, Toxoptera citricidus. This vector successfully transmitted the virus to West India lime seedlings grown under insect-proof conditions, producing the characteristic symptoms of vein clearing in approximately 23 days. Subsequently the symptoms of stunting of plants, curving and dwarfing of leaves, and chlorosis were observed. At the end of four months, corky veins, generally described for severe strains of tristeza and stem pitting symptoms, were produced on the inoculated plants.

Transmission to Orange Seedlings

In continuation of these experiments transmission was also made to orange seedlings grown under insect-proof conditions. T. citricidus fed on lime seedlings infected in the earlier experiments were used as vectors. Four cultivars of sweet orange seedlings were used; two local varieties, Bibile orange and Omanthai, and Valencia and Caipira; also some seedlings obtained from Washington navel. A continuous clearing of the secondary and tertiary veins in leaves was obtained at the end of ten weeks, except in Omanthai. Stunting and curving of leaves was hardly noticeable in Omanthai and Valencia, but occurred in other cultivars.

Transmission to Other Citrus

Further transmission experiments were carried out on Rough lemon, Tahiti seedless lime and Limonium, a hybrid lemon, as well as on local lime and West Indian lime. Lemon hybrid and seedless lime were obtained as cuttings from the field and rooted in pots. Rough lemon and other lime cultivars were raised as seedlings under insect-proof conditions and later established as root cuttings.

Rough lemon seedlings only showed a transient, faint vein flecking which was not continued in subsequent flushes. No symptoms were detected on the lemon hybrid. However, vein flecking was first observed on Tahiti seedless lime, but it was subsequently determined that this variety, which is propagated vegetatively, was already carrying a virus.

Further experiments established that the virus naturally found in the clone of seedless lime was identical with the virus found in sweet orange. An accurate comparison of the effects on infected seedless lime with uninfected plants could not be made owing to the unavailability of a virus-free clone of seedless lime. Tahiti lime, however, carried the virus with greater tolerance than did local lime or West Indian lime, showing very little stunting and reduction of leaves and much less chlorosis or stem pitting. The observation that Tahiti lime, and in a greater measure lemon hybrid, is more tolerant of the virus is confirmed by the fact that seedless lime and lemon hybrid on rough lemon stock have survived for many years in localities in Ceylon where sweet orange, mandarin, and local lime have failed.

Discussion

The symptoms produced in the lime seedlings of stunting, vein flecking, dwarfing curving of leaves, chlorosis, stem pitting, and formation of corky veins confirm that the virus found on the declining sweet orange in Ceylon is a strain of the tristeza complex. The prominent clearing of the secondary and tertiary veins on sweet orange seedlings, however, is a symptom that has not been normally reported for sweet orange. The vein clearing that is associated with the psorosis virus is of a different type to the condition described above. Grant (pers. comm.) has observed some vein clearing on sweet orange seedlings together with the retardation of growth and chlorosis which he attributes to an initial shock effect followed by some recovery and new growth. The condition observed on sweet orange seedlings here described may admit of a similar explanation.

The evidence so far accumulated points to the existence of a virus of the tristeza type in Ceylon citrus. The symptoms noted on the test lime seedlings of vein flecking, chlorosis, stunting, corky veins, and stem pitting are comparable to the symptoms produced by severe strains of tristeza observed in other countries. (Olsen, 1956). The prominent clearing of veins on initial infection on sweet orange seedlings, the fact that sweet orange declines on sweet orange stock, and further that sweet orange seedlings decline on their own roots is indicative of a severe strain of a virus.

Tristeza in other countries is mainly reported as important in citrus grafts. Whether this virus which effects seedling orange in Ceylon is a different strain of tristeza or whether local sweet orange varieties are more intolerant of the virus than those grown elsewhere is a question that cannot be answered with certainty at present.

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THE LATENT INFECTION PROBLEM IN THE CONTROL OF ABACA (MANILA HEMP) MOSAIC

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The control of abaca mosaic, the most important disease of this crop in the Philippines (Ocfemia, 1949; Kent, 1954; Reinking, 1955; Magee, 1957) has been handicapped because there is available to very few planters disease-free or even reasonably disease-free planting stock. It has been a common experience for planters to lose up to 25% or more of hills to mosaic during the first year of establishment of new plantations. In the early post war years losses were even heavier but considerable progress has been made by the Abaca Mosaic Control Unit

set up in 1950 by the Bureau of Plant Industry of the Department of Agriculture and Natural Resources (Cruz, 1956). Assistance was given to planters in the selection of disease-free or relatively disease-free seed-pieces from old plantations which had escaped the epiphytotic that threatened the industry with extinction during and after the Japanese occupation. The success of such plantations as TADECO & DAPCO and many smaller plantations at Compostela and other nearby districts can be attributed largely to the care exercised in selecting planting material.

During a survey by the writer of the infected areas in Mindanao towards the end of 1956 an interesting observation was made which throws some light on the difficulty that has been experienced in deriving healthy planting stock. The importance of primary or seed-piece infection in perpetuating the disease and disseminating it to new regions has been recognised for many years. As a result, it has become the practice for the abaca farmer when establishing new plantations to endeavour to obtain the best planting stock available and to rogue infected hills that may appear during the first few months, and refill the sites. Usually, three or four roguings are carried out. Typical figures of roguings from two plots that were examined are:-

Plot 1. 1st roguing 14.3%, 2nd 7.2%, 3rd 2.4%, 4th 7.6%

Plot 2. 1st roguing 19%, 2nd 8%, 3rd 1.5%.

Such figures are highly suggestive that infection is of primary origin; particularly when the spatial distribution of new outbreaks is plotted, as the late ones bear little or no relationship to earlier ones. It, nevertheless, appears to have been generally assumed that infected plants removed at the first roguing are mainly of primary or seed-piece origin, while those removed later are mostly secondary or vector-borne infections. This assumption has tended to cause abaca mosaic to be classified as a highly infectious disease, in spite of the fact that the vector aphids (Aphis gossypii, Rhopalosiphum nymphae, A. maidis) are not commonly found colonising abaca under field conditions.

Symptoms of Primary and Secondary infection

In published work no clear distinction has been drawn between the symptoms of primary (seed-piece) and secondary (aphid-borne) infection. It appeared to the writer, however, following field examinations of the disease, that such a distinction can be made (Magee, 1957).

The first symptoms arising as a result of aphid transmission are as originally described by Celino (1940) and Ocfemia and Celino (1941). These are small, pale, yellowish dots, appearing 8 to 10 days after inoculation, on the leaf blade of the first leaf, or occasionally of the second leaf, unfurling after inoculation. The small dots gradually elongate into streaks, with the central area of the dot remaining distinct for some time. In some plants, in addition to the yellow dots, yellowish diffused areas also appear. The leaf which emerges after the first-symptom leaf shows more advanced symptoms and usually pronounced mosiac mottling. There is usually evidence of a "virus shock" associated with this leaf in the form of a shortened leaf stalk and sometimes the leaf blade is also reduced in size.

It was the writer's observation that when the disease appears as a primary infection in a plant which is several months old, symptoms are first seen on the underside of the midrib and leaf stalk of an otherwise normal fully-expanded leaf. They are first detected as dark brown to black, elongated areas or streaks, or pale yellowish streaks which later darken. At this stage of the disease no sign of other abnormality can be detected on either the upper or lower side of the blade of the first-symptom leaf. There is no sign of virus shock. The next leaf which emerges is strangely free from any markings, either on the underside of the midrib or the upper or lower surface of the leaf blade, but occasionally there are one or more yellowish, bleached areas on the base of the leaf stalks. The next leaf which emerges, however, shows yellowish or bleached areas (which may darken) on the base of the leaf stalk and extending up and along the underside of the midrib; and the leaf blade for the first time shows symptoms. These may be yellow dots and spindle shaped streaks, or a diffused yellowish area extending out from darkened areas on the underside of the midrib, or both. The next leaf

may show similar symptoms or display the mature-type mosaic pattern.

This sequence of symptoms is an interesting one and, in fact, was the usual display of symptoms of abaca mosaic seen in the field by the writer while in the Philippines. The secondary type with the slight "shock" phase was relatively uncommon. The conclusion was hard to avoid that most of the new outbreaks occurring in young plantations had their origin as a latent infection in the planting material. In most plantings of which records of roguings were kept the majority of infected plants could be removed during the first 3 months after planting, but smaller numbers displayed symptoms for the first time over long periods, viz., 12 to 18 months or even longer. Some plants showed symptoms for the first time just as the inflorescence was emerging. The opinion was formed that this latency in display of symptoms was at the root of the difficulty which has been experienced in effectively dealing with abaca mosaic. Attempts to derive disease-free planting stock at the Southern Mindanao Regional Experiment Station over a number of years by roguing were only partly successful. Reluctance to rogue completely large abaca stools which showed partial infection for the first time late in growth appears to have been a problem at this Station.

Latency in display of symptoms of virus diseases in Musa spp. would seem to be a complication that must be given attention in any attempt to control such diseases by roguing or eradication. Experience in New South Wales in a well organised campaign to control the bunchy top virus disease of bananas by eradicative methods has, over the years, brought to light many instances where latency in display of symptoms has upset calculations. It is possible that the tendency of virus diseases to remain latent in the interconnected corm system of Musa spp. is related to the very large number of dormant "eyes" or growing points which are a feature of such systems. In the abaca plant, in particular, the corm system is a most intricate one.

It is not yet clear how the problem of latency of abaca mosaic can best be met. Among the recommendations made to the Philippine Government in this regard was the proposal that hill-row planting and roguing, which has long been found effective in dealing with potato virus diseases, be adapted to the abaca industry.

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LEAFROLL OF GRAPEVINES IN NEW SOUTH WALES

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A disease of grapevines which causes rolling of the leaves has been known in European vine growing areas for very many years under the name Rollkrankheit and a condition of reduced vigour and cropping has been attributed to it. In the U.S.A. also a leaf roll disease has been present for many years (Goheen et al. 1958) and, in addition to leaf rolling, causes premature autumn colouring and scorching of leaves, and in red fruited varieties, such as Emperor, a reduction of fruit colour (Hewitt, 1954). Its virus nature has been demonstrated by grafting (Harman & Snyder, 1946), but though an insect vector has been suspected none has yet been definitely established.

A type of degeneration of vines has become pronounced during the past ten years in three areas of New South Wales and on the basis of symptom development and transmission to indicator varieties it is diagnosed as being due to the presence of leaf roll virus. It appears probable that the disease has been present for many years.

Grape Growing in New South Wales

Varieties and districts: Grapes are grown for fresh fruit, for wine making, and for drying in three main climatic zones in New South Wales:

(a) In the coastal section, under natural rainfall (25 to 35 inches per annum) without supplementary irrigation, table grapes (Black Muscat, Rosaki, Muscat Gordo Blanco, Cornichon) are grown in the vicinity of Sydney, and wine grapes (Semillon, Shiraz, Ugni blanc, and minor plantings of Chasselas Dore, Pinot, Traminer, and some others)at Rooty Hill, near Sydney, and in the Hunter River Valley near Cessnock.

(b) In the central tableland area under natural rainfall (22 to 35 inches per annum) without supplementary irrigation, table grapes (Black muscat, Muscat Gordo Blanco, Rosaki and minor varieties) are grown in the Orange, Molong, and Mudgee districts, with a small area of wine grapes at Mudgee.

(c) In the inland area (i) under natural rainfall (28 inches per annum) without supplementary irrigation, in old established vineyards at Corowa wine grapes are grown (Grenache, Shiraz, and a rather large number of minor varieties); (ii) under irrigation and in a much warmer climatic area in the Murrumbidgee Irrigation areas. In this large and extending area wine grapes are the most important crop and the main varieties grown are Grenache, Semillon, Shiraz, Ugni Blanc and Doradillo. Some table grapes (Cornichon, Rosaki, Ohanez) are also grown; (iii) in extensive plantings along the lower part of the Murray River the variety Sultana is grown mostly for drying. There are also some smaller plantings of Gordo Blanco, Rosaki, Zante currant and wine varieties.

Rootstocks: Except at Corowa and in the area round Sydney (including Rooty Hill) vines are self rooted. Phylloxera-resistant stocks are used in these two areas. A fairly large range of stocks is grown in Viticultural nurseries maintained by the new South Wales Department of Agriculture, and rooted cuttings are sold to growers.

The Leaf Roll Disease

Vines affected with leaf roll disease are lacking in vigour and do not crop heavily, but they show no definite abnormality during the early part of the season. As the crop approaches maturity in mid to late summer, the symptoms of leaf roll appear, the older leaves become somewhat thickened and rough and rather harsh to the touch, at the same time,in white fruited varieties, there is some bleaching and yellowing, followed by scalding, particularly of marginal parts of the leaves. Dark fruited varieties at this stage show reddish, interveinal colouration. A tendency for leaf margins to roll downwards accompanies the thickening of leaves, becoming evident first in later midsummer and intensifying after harvest.

Affected vines are staggy and the general habit of growth is rather upright and stiff as compared with the spreading habit of healthy, vigorous vines. The root system is poorly developed, showing a gradual deterioration from the early years of growth.

The type of symptom developed and its severity has been observed to vary with locality, seasonal conditions, and variety. As in California and Europe (Goheen et al., 1958) leaf roll-affected vines are much more influenced by adverse seasonal and environmental conditions than are virus-free vines. In a good season and under good management an affected vine may approach the production of a healthy vine, whereas in very dry years production is greatly reduced. Under irrigation, cropping and vigour are less reduced than under natural rainfall, though the symptoms of leaf rolling are usually very marked. The ability to respond to good seasons and treatment becomes less with age.

Varieties affected: Chasselas Dore, which is grown at Rooty Hill and to a minor extent at Corowa and in the Hunter River area, appears to be almost 100% infected. It shows very marked leaf rolling and some scalding and reduction in vigour and cropping. Leaf roll affected vines have a tendency to hold their leaves later in the season than healthy vines. Young vines show first symptoms relatively early under field conditions. Some rolling has been observed in 2- and 3-year old vines, before crops of any size are produced. Traminer, which is grown at Rooty Hill and to a minor extent in the Hunter River area, shows a rather high percentage of infection. Leaf rolling is not a prominent feature in this variety, but leaf scalding, and deterioration of vigour occur. Young vines are vigorous and free of symptoms for the first four years of growth. Infection in Semillon, one of the most widely grown varieties, is variable, some vineyards being totally infected, some quite free of the disease, and some showing from a trace to 50% or more. Leaf rolling is pronounced, particularly late in the season, and bleaching and scalding of leaves also occur. The tendency for leaves to be retained longer on leaf roll-affected vines than on healthy vines is noticeable in this variety as in Chasselas Dore. Semillon is a very vigorous variety and the depressing effect of leaf roll infection is less marked, particularly in the early years of growth, than in Chasselas. The effect of adverse seasons also is less marked than in Chasselas.

The varieties Grand Noir and Alicante Bouschet grown at Corowa, and Black Pinot, grown at Corowa, Rooty Hill, and in the Hunter River area, appear to be totally infected; no vines completely free of symptoms have yet been located. They are of low vigour, show pronounced leaf roll and early development of red colouration in the leaves. Young vines of Black Pinot are reasonably vigorous and symptom development is not pronounced during the first 6-8 years. The variety White Tokay grown at Corowa appears to be totally affected.

A low percentage of vines of Grenache and Monbaden in Corowa vineyards show pronounced symptoms of leaf roll, accompanied by deteriorating vigour, but elsewhere in the State Grenache appears to be free of infection.

The variety Doradillo shows 10 to 20% infection in some vineyards, leaf rolling being particularly strongly developed late in the season.

Extensive surveys have shown no evidence of leaf roll in the important dried-fruit variety Sultana, nor in the widely grown varieties Shiraz and Ugni blanc.

Transmission: The wine variety Mission and the stock variety Vitis rupestris St. George which are used in California as test varieties for leaf roll were obtained by the courtesy of Professor W. B. Hewitt of Davis, California, in March, 1958. Canes of these varieties were inoculated by chip grafts from vines of Chasselas Dore, Traminer and Semillon and grown under quarantine conditions. These inoculated vines subsequently developed symptoms of the leaf roll virus (Fraser, unpublished).

Means of Spread; The principal, if not the only means of spread of the leaf roll virus in New South Wales appears to be by the use of infected propagating material

In Hunter River vineyards infected Semillon and Black Pinot have been grown for many years close to leaf roll-free Shiraz and Ugni Blanc and there is no

evidence of spread to these. At Rooty Hill, plantings up to 80 years old are very mixed and a number of minor varieties are scattered through infected blocks of Chasselas and Traminer. These are all virus-free and of considerable vigour. At Griffith, in the Murrumbidgee Irrigation areas, there is no evidence of spread from infected Semillon to other commercial varieties.

At Corowa the occasional leaf roll-infected vines of Monbaden, and of Grenache, a variety which in other parts of the State is without symptoms, may indicate that insect transmission can sometimes occur.

Association with Potassium Deficiency Symptoms: The symptoms of leaf roll approach rather closely to those of potassium deficiency. This has been noted in California and Europe (Goheen et al., 1958) and the similarity has been observed also in New South Wales. In the Rooty Hill and Hunter River areas soils are rather low in available potassium, though not at the deficiency level. It is in these areas that K-deficiency type of leaf pattern is most strongly developed in leaf roll-affected vines. Analyses of leaf samples from virus-free vines, vines with severe leaf roll symptoms, and vines with mild leaf roll symptoms in the same vineyeard (unpublished) show that the level of potassium is lower in affected than in healthy vines. This may indicate that leaf roll affected vines have a reduced ability to absorb potassium and are, therefore, likely to show symptoms of K-deficiency in soil which supports the healthy growth of leaf roll-free vines. This association with potassium deficiency symptoms has also been observed in vines affected by nematodes, or Phylloxera (Cook & Kishaba, 1956).

Variations in symptom severity: The varieties most intensively studied, Chasselas Dore, Traminer, and Semillon exhibit a considerable range in severity of symptom expression. In the one vineyard some vines show extreme stunting and scalding, others are of moderate vigour, others nearly normal; leaf rolling in some vines commences in midsummer, in others is delayed until after harvest. The intensity of rolling also varies from slight, affecting the older leaves chiefly, to severe, in which all leaves are rolled at the end of the season. The possibility of the existence of strains is being investigated.

Control

Surveys have shown that leaf roll is a major factor in causing deterioration of vines in three areas of New South Wales, Rooty Hill, near Sydney, the Hunter River district, and Corowa, and that it is present in several varieties in the Murrumbidgee Irrigation area. The acreage involved is not large in comparison with the total area of vines in the State and the number of infected varieties is small. However, the varieties affected are valued for special purposes and it is desirable that virus-free material should be made available to growers if it can be obtained. During the last three years, close observations have been made on a number of blocks of Chasselas Dore, Traminer, and Semillon and vines selected, which, during that period, have shown no visible symptoms of leaf roll. These are being indexed by grafting to canes of the indicator varieties Mission and V. rupestris St. George.

It is planned to build up virus-free stocks of these varieties, if such can be found, and to extend the survey gradually to cover all varieties grown.

Phylloxera-resistant, hybrid stocks are for the most part symptomless carriers of leaf roll (Goheen et al. 1958). It is therefore necessary also to index mother vines of stock varieties maintained by the New South Wales Department of Agriculture, and this work has been commenced.

Although leaf roll does not constitute a threat to the grape growing industry its effects are serious in those restricted areas where it is present. It does not cause large scale or rapid loss of vines, but by reducing vigour and cropping, makes the growing of these vines uneconomic in most years.

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THE GENETICS OF YELLOW RUST RESISTANCE IN WHEAT

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The Mendelian basis of the inheritance of wheat to yellow rust (Puccinia glumarum) was first demonstrated by Biffen (Biffen 1907) who showed that resistance to this disease in a number of crosses was determined by a single recessive factor. Although the importance of his pioneer experiments cannot be denied, it should be pointed out that his investigations were carried out under field conditions and were based on infection by a naturally occurring rust epidemic. A number of papers on the inheritance of resistance to known races of P. glumarum has since been published (e.g. Straib, 1939; Favret and Vallega, 1953). Our knowledge of the genetics of resistance is, however, quite inadequate when consideration is given to the number of physiologic races which have since been identified and to the range of resistant varieties now available to the breeder.

A programme of research into the inheritance of disease resistance in cereals is being conducted at the Plant Breeding Institute, Cambridge. In this programme four physiologic races of P. glumarum, identified as physiologic races 2B, 5, 8, and 8B have been used. The inheritance of resistance to these races has been investigated in a diallele series of crosses comprising seven varieties of Triticum aestivum: Cappelle Desprez, Chinese 166, Heine VII, Holdfast, Hybrid 46, Minister and Soissonais; the reactions of these varieties to each of the physiologic races is shown in Table 1. The reactions of F1, F2, and F3 generation seedlings have been investigated. A full account of the techniques used and of the results obtained is now being prepared for publication (Lupton and Macer, 1961).

TABLE 1

Reactions of seven winter wheat varieties to Puccinia glumarum

	Reaction to Puccinia glumarum		
	Race 2B	Races 5 & 8	Race 8B
Capelle Desprez	III-IV	0	0
Chinese 166	00	00	00
Heine VII	0	0	IV
Holdfast	III	III-IV	IV
Hybrid 46	0+IV	0-00	0-00
Minister	0	0	0
Soissonais	0	0	IV

As a result of these investigations it has been possible to identify the genetic factors determining the reactions of the varieties tested to the four physiologic races. It has been found that four loci, which have been denoted by the symbols Yr1, Yr2, Yr3 and Yr4, are involved in determining rust reatcions. Single

alleles have been found at loci Yr1 and Yr2. Three alleles have been identified at Yr3 and two at Yr4. The genetic control of rust resistance in these varieties thus appears to be determined by a relatively simple major gene system, similar to that which Knott has shown to determine resistance of wheat to black stem rust (Puccinia graminis var. tritici) (Knott, 1957).

Exact information concerning the genetic basis of disease resistance is of the greatest value to the plant breeder. With such knowledge it is possible to draw up an improved range of differential hosts by which the physiologic races of the fungus may be identified in terms of their reactions on host plants which carry known resistance factors. Such knowledge also enables the breeder to choose parents for hybridisation which carry differing resistance factors, and which can therefore combine in their progeny independently inherited factors for resistance.

Another approach to the problem of disease resistance, which has become possible as a result of a knowledge of the genetic basis of resistance, involves the use of backcrossing programmes to introduce new resistance genes to otherwise desirable varieties before they are used as parents in the general breeding programme. Genes conferring resistance to yellow rust and to powdery mildew (Erysiphe graminis) are being used in this work which may be illustrated by the following example.

The variety Professeur Marchal shows considerable promise in Britain but is susceptible to mildew and also shows some susceptibility to yellow rust. By a backcrossing programme it has been possible to develop a rust- and mildew-resistant selection which closely resembles the widely grown variety Cappelle Desprez. Before Professeur Marchal is used as a parent in the general breeding programme, it is crossed to this rust- and mildew-resistant line and the F1 backcrossed to Professeur Marchal. Rust- and mildew-resistant plants derived from this first backcross are then used as parents in the general breeding programme. Although these backcrossed plants will differ from Professeur Marchal in some respects the potentialities of the crosses will be greatly increased since it will be possible to select for rust and mildew resistance within them.

Discussion has so far been confined to resistance determined by major genes, the operation of which can be detected at the seedling stage. There is, however, another form of resistance, known as field resistance, which may be of considerable importance in determining the reactions of plants under agricultural conditions. Little is known of the inheritance of this form of resistance, although it appears to be polygenically determined, and is therefore unlikely to break down if new physiologic races of the pathogen should arise. There is little doubt that some of the older varieties cultivated in Britain exhibited a high expression of this form of resistance, and it is also shown by a number of the varieties at present in cultivation. Field resistance is a more difficult character for the plant breeder to work with than resistance determined by major genes, especially in the presence of such major genes. It is important, however, that such resistance should not be overlooked, but that it should be combined where possible with major gene resistance in the breeding of new varieties.

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BASIC ASPECTS OF BREEDING RUST RESISTANT WHEATS

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Summary

It is now well known that the variability in the rust organisms present a major problem in the breeding of rust-resistant wheat varieties. In Australia, despite the absence of an alternate host in the wheat districts, new strains of leaf rust and of stem rust are continually arising. Their pathogenicity on a series of differential varieties selected for each organism indicates that they are varying around a pattern characteristic of this geographical area, in which New Zealand is also represented. Results obtained on differential varieties selected overseas are of limited value here in the overall problem of classifying the strains that are present.

New strains of rust arise in at least 3 ways. Mutations usually resemble the parental strain very closely and differ from it on one or perhaps 2 varieties carrying dissimilar genes for resistance. Somatic hybrids arise as a result of some form of hybridization on the cereal host which is at present not understood. The most spectacular changes in pathogenicity occur when strains are inbred or when they are crossed on the alternate hosts, either Berberis or Thalictrum.

Successful results from breeding only follow when there is a detailed knowledge of the strains of rust present in the particular area and when the genes for resistance in the host plant have been well catalogued. Some progress in Australia was made using the genes from Kenya wheats such as Sr_6 on chromosome XX and a gene on chromosome X which has been called $Sr_{11}Sr_{12}$. These genes have now become ineffective, but Sr9 on chromosome XIII is still highly effective and this gene, or alleles of it, are present in the varieties Moora, Kenora, and Gamenya. New varieties are about to be released with the genes for stem rust resistance originally from Triticum timopheevi and very attractive material is available with its resistance from Khapli Emmer (T. dicoccum).

Breeding wheats for resistance to stem rust Puccinia graminis Pers. var. tritici (Eriks. and E. Henn.) and leaf rust P. recondita f. sp. tritici in Australia has been carried on for approximately 40 years and summaries of the progress made have been issued from time to time (Waterhouse, 1952; Watson, 1958). While the breeding programmes have not resulted in the complete answer to the problem of rust control definite results have been obtained. The varieties of today have a greater inherent resistance than those of former years and conditions must be extremely favourable for widespread damage to be done.

During the course of these attempts to control the organisms it has become increasingly apparent that certain fundamental aspects of the problem must be studied in association with the breeding programme. Any success that may have come in this work stems from a recognition of this fact. The three most important aspects appear to be: (1). epidemiology, (2) variation in the organsims, and (3) sources of resistance in the host.

EPIDEMIOLOGY

The work commenced in 1921 by Waterhouse has clearly demonstrated the changing nature of the two organisms responsible for these diseases in Australia. These changes, which are well known to rust workers as occurring all over the world, have been followed by means of annual surveys of inoculum collected widely throughout the area where wheat is grown.

The first collections of leaf rust and stem rust were shown to be of strains vastly different in pathogenicity pattern from those now prevalent and they possibly represent the original combination of genes for pathogenicity that were then present, although the exact origin of wheat rust in Australia is not known. Stem rust may have been present for many years prior to the cultivation of wheat and

its persistence could have been possible on the perennial native grass Agropyron scabrum (R. Br.) Beauv. No existing species of grass is known to harbour the wheat leaf rust organism in Australia and it may have arisen from one of the many other leaf rusts present on grasses.

When Waterhouse commenced his studies he separated several strains (then called forms) by the use of pathogenicity tests on varieties that had been selected as differentials by overseas workers (Waterhouse, 1929). These were appropriately described according to a system which was designed to get coordination of variability studies made in different countries. It soon became apparent that in the case of P. recondita overseas varieties were inadequate for the determination of important phenotypic differences between the Australian strains. The variety Thew was an essential differential here, but apparently of no value in the United States.

Such a finding was at first of academic interest and it was not until the first products of breeding programmes became available for commercial use that its full significance was appreciated. Eureka was the first widely grown variety with resistance to stem rust and its susceptibility after four years of cultivation has already been described (Watson, 1958). Subsequent varieties such as Gabo suffered the same fate with the appearance of new undescribed pathogenic strains. New differentials had to be found to determine strain prevalence in any one area. A similar happening was found in P. recondita where the widespread cultivation of Gabo lead to a segregation of strains virulent on the parental variety Gaza. The cultivation of Spica resulted in a build up of strains virulent on that variety so that Thew, Gaza, Spica, and now Kenya 1483 are essential in any leaf rust survey work (Watson, 1958, and unpublished).

The occurrence of new strains underlined the urgency for more critical information from a survey more systematically conducted. Hence, in 1953, chance collections were supplemented by those from areas sown with very susceptible varieties in a scheme that has grown to a stage where approximately 400 experimental sites are established throughout Australia, New Zealand, and New Guinea. Valuable co-operation comes from school teachers, farmers, agronomists, and others who collect from the susceptible material and forward it for identification. Cultures are established in the glasshouse and are used to inoculate the differential varieties that are useful in this region, and also to inoculate the various sources of resistance used by the plant breeders. It was from susceptibility of Celebration (Marquillo resistance) that the first significant results of this method became evident. Marquillo was at that time a valuable source of resistance to stem rust.

It was recognised in the early stages of this work that the strains of stem rust prevalent in Australia from 1925 to 1954 were in many respects very similar. They differed very markedly, however, when compared on the varieties which provided the source of resistance in the commercial varieties. On the overseas set of varieties they would have been called sub-races of races 126 and/or 222, which in Australia are characterised by virulence on Mindum, Arnautka, and Spelmar at temperatures of 80 - 85°F. and avirulence at 65 - 70°F. Moreover each was virulent on Mentana, some were virulent on varieties with the gene Sr_6, others were avirulent.

Late in 1954, a new strain of stem rust 21 Anz-1 was isolated from south-eastern Australia and was quite unlike any strain that had been found in this area previously (Watson, 1955), although Waterhouse (1952) had found race 21 on one occasion from the southern tablelands. In contrast to the strains found previously, 21-1 was not sensitive to changes of temperature when on the varieties Mindum, Arnautka and Spelmar.

It was avirulent on Kanred, only weakly virulent on Mentana, but virulent on Marquillo, except at temperatures of about 65°F. The resistance of Eureka and similar varieties with Sr_6 broke down at lower temperatures with this strain than with strains 126-1, 126-3, and 222-2. Presumably it had arisen from barberries in Tasmania (Watson and Luig, 1958a, 1958b) as it was well established there in January 1955 (Watson, 1955).

The occurrence of such a strain represented a new era in the stem rust flora

in Australia, combining as it did a new set of phenotypic characters. Such a dramatic change had not occurred in Australia since 1925 when form 34 was first recorded (Waterhouse, 1952). Strain 21-1 was aggressive and it was dispersed to the northern part of the eastern wheat belt where it presumably underwent somatic hybridization with strain 222-2 and, from the cross, strain 21-2 with added virulence on Gabo resulted (Watson and Luig, 1958b). The movement of this latter strain was then in a southerly direction so that it occupied the whole of the eastern wheat areas. It was found in New Zealand in 1959 (unpublished). These movements are shown graphically in figure 1.

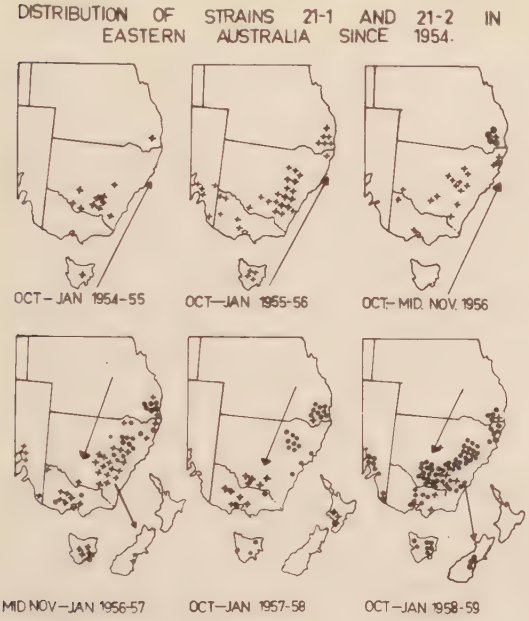

Fig. 1.

The movement of strain 21-1 north in 1954-55 and the movement of strain 21-2 south in 1956-59.

The presence of this new strain 21-2 in great abundance provided ample opportunity for somatic hybridization with other strains and this appears to have taken place. New strains isolated since 1954 have predominately the characters of strain 21-1 as shown below.

CHARACTERS OF STRAINS PREVALENT PRIOR TO 1954
(126-1, 126-2, 126-3, 222-2, 222-3)

1. Virulent on Reliance and Kanred
2. Virulent on Mentana
3. Weakly virulent on Acme
4. Virulent or avirulent on Eureka Sr_6
5. Avirulent on Celebration
6. Reaction on Mindum sensitive to temperature

CHARACTERS OF STRAIN 21-1 ISOLATED 1954

1. Avirulent on Reliance and Kanred
2. Weakly virulent on Mentana
3. Virulent on Acme
4. Avirulent on Eureka
5. Virulent on Celebration
6. Reaction on Mindum not sensitive to temperature

CHARACTERS OF NEW STRAINS ISOLATED 1956-1960
(21-1, 21-2, 34-1, 34-2, 34-3)

(1) Virulent or avirulent on Reliance and Kanred.

(2) Virulent or weakly virulent on Mentana.

(3) Virulent on Acme.

(4) Avirulent on Eureka.

(5) Virulent or avirulent on Celebration.

(6) Reaction on Mindum not sensitive to temperature.

The basic characters of the strains now prevalent are mainly those of strain 21-1, which it appears has contributed to their parentage. Some of these strains have gained genes for specialised abilities which are essential for their survival in the population.

In view of the ready distribution of spores by wind throughout the wheat belt of eastern Australia and to New Zealand (Waterhouse, 1952; Watson, unpublished) and in view of the variation of the organism around a certain basic pattern, it was clear that Australia and New Zealand were in the one geographical area for the purpose of rust spore dispersal. This justified a co-ordination of the epidemiology studies in the two countries. For this reason the letters Anz have been affixed to the designation for each strain collected in the area since 1955. In the complete designation of the strain, acknowledgement is made of the fact that such data have been collected on the varieties of Stakman and Levine, even though local varieties are more important for differentiation. Thus, the common strains at present 21 Anz 1, 21 Anz 2, 34 Anz 2, 34 Anz 3, and 126 Anz 1 give, on the Stakman series, the reactions of race 21, 34, and 126. The second number in their full classification is the reaction on the local varieties (Watson 1955).

All collections received during the season are not tested on the Stakman and Levine series. Representative samples are placed on them throughout the survey season and their reaction recorded. It can be seen from Table I that this series is of little value when compared with the local series for separating strains 222-1, 222-2, 222-3, and 222-4.

TABLE I

Reaction of 4 strains of wheat stem rust when placed on to the Australian supplemental differentials

Strain	Reaction on the Stakman & Levine series	Reaction on Australian differentials				
		Bok-veld	Yalta	C.I. 12632	Mentana	Celebration
222 Anz 1	Race 222	R	R	R	S	R
" 2	" "	R	S	R	S	R
" 3	" "	S	S	R	S	R
" 4	" "	S	S	S	S	R

R = Resistant S = Susceptible

New varieties are continually being developed as genetic stocks to facilitate the easy detection of strains either in the plant breeding nursery or in the laboratory. Varieties such as Eurga which combine the resistance of Eureka (Sr_6) and Gabo ($Sr_{11}Sr_{12}$) are especially valuable for the detection of those strains having the ability to attack lines with both types of resistance. It is not proposed that the

local varieties shall be a fixed group. Should a set become inefficient it will be replaced by a more suitable combination so that the strains may be isolated and described more readily. As far as possible, a continuity of basic host genes for resistance will be preserved in the differentiating varieties so that strain relationships over long periods can be traced.

VARIATION IN THE ORGANISMS

Under Australian conditions new strains of rust may arise in at least three ways: (i) somatic hybridization (Watson and Luig 1958b), (ii) mutation and (iii) sexual hybridization.

(i) Somatic hybridization: Nelson, Wilcoxon, and Christensen (1955) first described the production of new strains arising from mixtures of uredospores of previously existing strains. Unstable cultures virulent on Khapli were found to dissociate to stable dicaryons with a pathogenicity pattern unlike that of the parental cultures. This initial study has lead to several pieces of independent work which has shown clearly that, provided the screening procedure is adequate, strains unlike the parental strains in pathogenicity can be readily obtained by mixing uredospores on the uredial host (Watson, 1957b; Vakili and Caldwell, 1957; Flor 1960).

This approach to the origin of new strains of cereal rusts is of great importance in Australia where the distribution of barberry is so restricted and the infections so sporadic. It must also be of paramount importance there for leaf rust (P. recondita) and, in fact, for all countries where natural infection of the alternate host (Thalictrum sp.) is not known to occur.

The nature of the process whereby new strains are produced in this way is not yet understood and a great deal more work is required. From the work of Nelson (1956) and of Bridgmon (1959) it would appear that the dominance relationships for virulence and avirulence and for spore colour are upset when these asexual variants arise. For example, Nelson found that orange cultures, which on present knowledge would be expected to have only one of the two dominant genes concerned with spore pigmentation, dissociated to give some cultures with grey-brown spores, others with red spores. This suggests that the orange cultures have lost one of the dominant genes and gained the other to give grey-brown spores, and gained one dominant to give the red spores. Such changes from orange to grey-brown and from orange to red are difficult to explain if we regard the basis for spore colour inheritance established by Newton et al. (1930) as correct. All attempts to observe such a happening in our laboratories have failed; orange cultures have always produced orange progeny if grown on the uredial host.

Anomalies resembling these were obtained by Bridgmon (1959) for pathogenicity. He mixed cultures which were virulent on Einkorn and which presumably carried the recessive gene for virulence on this variety. A number of cultures avirulent on Einkorn were recovered. These presumably carry the dominant gene for avirulence.

It appears from the work of Wilcoxon et al. (1958) and of Manners and Bampton (1957) that the fusion of germ tubes provides a means whereby nuclei carrying genes for contrasting characters may come together in the same hypha. Such fusions were considered by Nelson to make possible the "transfer and regrouping of nuclei" and thus "result in the production of biotypes genetically different from the original parent biotypes". Flor (1960) also suggests nuclear exchange as the explanation for asexual variants, but considers mutation is also important.

A mechanism other than nuclear exchange must be involved to explain the whole range of progeny that can result from mixing two parental strains on the cereal host. Watson and Luig (1958b) obtained 11 different strains from such a pairing, and Vakili and Calwell (1957) obtained many more in P. recondita. Preliminary unpublished work by Watson and Luig suggests that the nuclei do not remain intact during this hybridization process. Those workers (1958b) consider that some form of nuclear fusion and recombination occurs, and as such would explain the whole range of types they obtained.

While the details involved in the process remain to be worked out its importance cannot be overlooked. The origin of the prevalent field strain 21-2 by this means

has already been mentioned. Moreover, work done simultaneously by Bridgman and Wilcoxon (1959) and Watson and Luig (1959) show that somatic hybrids can readily arise by crossing P. graminis var. tritici and P. graminis Pers. var. secalis (Eriks and E. Henn.). This is of some importance in Australia where the rye stem rust fungus has become very widespread since the first report by Waterhouse (1957).

The question could be raised as to whether the occurrence of somatic hybridization would reduce the effectiveness of barberry eradication in the control of P. graminis. In countries where barberries occur, but in which no eradication has been undertaken, this would need to be considered before legislation was enforced. The whole situation must be studied in the light of the well established facts that where barberries are heavily infected regularly they can become a source of inoculum early in the season, and, moreover, that sexual hybridization must always remain a more efficient mechanism for gene recombination and segregation than vegetative hybridization.

ii. Mutation: This has long been recognised as a means by which new pathogenic strains of both stem rust and leaf rust may arise, but little work has been done with cereal rusts to determine the frequency of mutation either spontaneously or under the action of mutagenic agents. In selection experiments with unusually coloured strains Watson (1957) was able to increase the range of pathogenicity by selecting mutants which were virulent on the variety Lee. In the case of one of these variants it has been shown that the mutant character can be readily transmitted to the progeny by somatic hybridization (Watson and Luig, 1958b). Mutations usually only involve changes in pathogenicity of a simple type, that is, one or at the most two host genes for resistance separate the mutant from the parental type. Thus, in the above experiments the writer found that Lee and all varieties having that type of resistance separated the mutant from the parent. No changes in pathogenicity were found on Bowie and it was concluded that the genotype of this variety was more complex or that mutation to virulence occurred in some genes of the fungus more readily than in others.

Flor (1958) has clearly shown that in Melampsora lini genes of the pathogen that undergo mutation most readily under the action of mutagenic agents are also the most unstable under natural conditions. Although this difference has not been demonstrated in the cereal rusts it is possible to build up virulence very readily in the leaf rust organism by a series of step-wise mutations for virulence on the varieties Thew and Norka. A single spore culture of strain 163-Anz 1 was built up on Federation selected on Thew to give the strain 163-Anz 2. This was again increased and selected on Norka to give the strain 122-1 thus:

Original Strain	163-1	163-2	122-1
Thew	R	S	S
Norka	R	R	S
Spica	R	R	R

R = Resistance

S = Susceptibility

The avirulence on Spica, which characterized the original strain and which is unusual among Australian leaf rusts, has been unchanged during the course of these selection experiments.

Mutation is an obvious means by which rust strains increase their host range. Flor (1960) considers that this process combined with nuclear exchange can explain all the asexual variants he obtained in Melampsora lini. Such an explanation does not seem possible with P. graminis var. triciti as mutants do not appear readily in all cultures. Attempts to produce the prevalent strain 21-2 by mutation and by somatic hybridization were made. Selections of an orange mutant of strain 21-1 on more than 100,000 heavily infected seedlings of Charter in which over 50 suspected variants were examined, failed to uncover one mutant type more virulent than the original parent. In the cross 21-1 (orange) × 222-2 (red) however, strain 21-2 together with other strains was readily recovered as a somatic hybrid in the progeny. In other work by the writer (Watson, 1957a) it was not possible to obtain mutants from red race 111 when the latter was screened for mutations for virulence at loci

known to be heterozygous in this culture (Wilcoxon and Paharia, 1958). When the latter was mixed with another strain Nr-2, however, the heterozygosity of several loci became evident and segregation occurred (Watson, 1957b; Watson and Luig, 1958b). New genetic material may arise by mutation and it may then be rearranged by somatic hybridization.

iii. Sexual hybridization: The potential danger of the alternate host of P. graminis has long been recognized wherever wheat is grown, even though sexually formed progeny may not always survive (Roane et al: 1960). Barberries can also be a menace in Australia since they are so widespread in Tasmania. Experiments now in progress by my colleague Mr. N. H. Luig give some guide as to the strains that will arise should barberries become infected by the strains now prevalent. From his work it has been shown that whereas Einkorn and Vernal Emmer are resistant to all common strains, yet isolations can be made from barberries of several strains to which they are susceptible. C.I. 12632, a valuable source of resistance, has also been found susceptible to certain isolates from barberry. On the other hand, Khapstein W. 1451, a derivative of Khapli Emmer, and Kenya 117A W1347 have not been susceptible to any of the barberry isolates. This would suggest that the genes for virulence on these two latter varieties are not present in the Australian strains of stem rust and consequently, as recessives, they do not become manifest with inbreeding on the alternate host. Should commercial varieties be released with these sources of resistance then mutation to increased virulence may be the means by which they become susceptible.

Under Australian conditions the present evidence indicates that the sporadic infection of barberries can result in the production of new strains possessing many characters unlike those of the existing strains. Should any one of such strains become widespread in the wheat districts, as we believe happened with 21-1 in 1954, then it is free to mutate and undergo somatic hybridization with existing strains to give important variation but of a lesser magnitude than would be expected with sexual hybrids.

THE SOURCES OF RESISTANCE IN THE HOST

The progress made in the breeding of rust-resistant wheats and the prospects for the future have already been summarised (Watson, 1958). Such breeding work, although conducted simultaneously at a number of centres throughout the Commonwealth, is closely co-ordinated with the nation wide strain survey of both the leaf and the stem rust organisms. As these surveys are designed and conducted in a way to meet primarily the needs of the wheat breeder, the information is passed on as effectively as possible so that new and promising sources of resistance are distributed for utilization.

Geographically, the country has two main zones separated by extensive desert. Between the zones strain differences are very marked and a knowledge of the reaction of the parental varieties is very essential. The eastern zone comprises an area where there is a ready movement of spores in a northerly and southerly direction and there is little exchange of inoculum with the western zone. Spore material may move from Queensland through New South Wales to South Australia. The Western zone comprises the wheat districts of Western Australia where the stem rust flora has remained reasonably static over the past 35 years. Gabo and related varieties still provide a valuable source of resistance there. Movement of spores into this area from the east is a rare event and only recently (unpublished work) has there been convincing evidence that it occurs.

The sources of resistance available to breeders are not numerous and what there are have been described (Watson 1958). Since that time stem rust resistant varieties have become available commercially (Table 2).

It will be seen that 3 of the varieties mentioned owe their resistance to Sr_9, a gene present in chromosome XIII. The resistances of Kenya 744 and Kenya 117A are allelic, if not identical. This resistance is not of an immune type, but under conditions of commercial cultivation it is probably adequate. When average temperatures are over 80^{o}F. a considerable amount of stem rust may develop on varieties having this type of resistance, but the reactions still show varying grades of resistance.

TABLE 2

Variety	Source of Resistance	Reaction predicted	
		Stem rust	Leaf rust
Moora	Kenya 744 (C. 6041)	Resistant to all strains	Susceptible
Kenora	" "	" " "	"
Gamenya	Kenya 117A W. 1347	" " "	Susceptible to Strain 163-3
Hopps	Probably Hope	Susceptible to Strain 21-4?	Susceptible
Mengavi	C. L. 12632	Susceptible to Strains34-3, 222-4	Susceptible to Strain 163-3

In contrast with this is the reaction of Mengavi, in which the resistance is very specific and, providing strains 222-4 and 34-3 are absent, it shows no rust development. In figure 2 the resistance of Gamenya and Mengavi are compared graphically and the specificity mentioned above is very apparent.

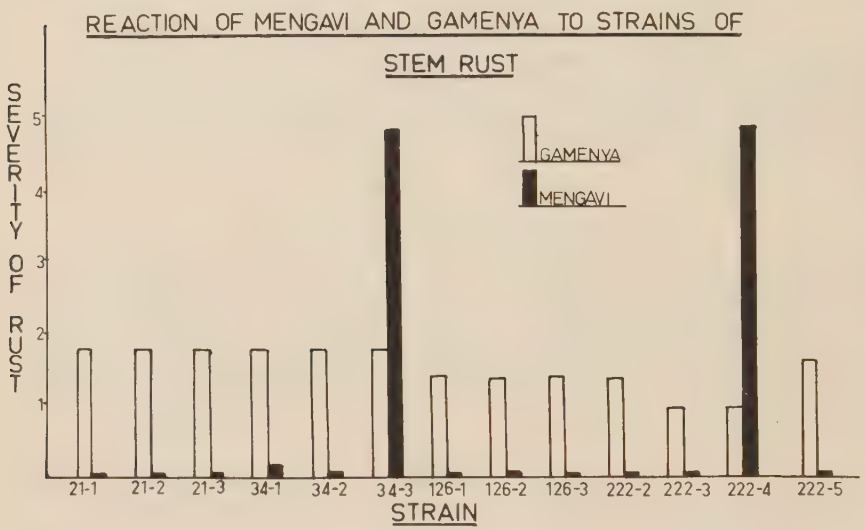

Fig. 2. Graphic representation of the severity of stem rust on two wheat varieties with different types of resistance.

Each of these varieties is a backcross derivative of the variety Gabo and is very desirable in yield and quality (Watson, Matheson and Bond, 1960). Under normal growing conditions their field reaction has been rather similar, but laboratory tests show great differences between them. The resistance of Gamenya as measured on the severity scale is more or less the same regardless of strain. Certain strains such as 222-2 and 222-3 give a lower reaction than the others, but the differences would probably not be important in the field. The behaviour of this variety suggests that should further strains of stem rust arise it will react in much the same way to them. If this prediction is correct considerable confidence can be placed in the stability of this variety in its reaction to rust.

By contrast Mengavi fluctuates very considerably in the reaction to stem rust, depending on the strain involved in the attack. When strain 21-2 is responsible for an epiphytotic the resistance of Mengavi is spectacular and borders onimmunity.

It does not appear to be as reliable as Gamenya, however, since strains 34-3 and 222-4 attack seedlings. These strains have only been found on one occasion in the field so their effects are still not fully known.

The differences between the two are such as to warrant discussion on the value of selecting for the high specificity shown by Mengavi in preference to the less effective but more comprehensive resistance of Gamenya to the prevalent strains. This point has already been raised by Griffiths (1958), but it is still too early to predict the future of these two varieties under Australian conditions. It would appear, however, that Mengavi will become a very suitable medium for the screening of strains 34-3 and 222-4, as well as virulent mutants or hybrids should they arise in P. graminis var. tritici.

Each of these two varieties has given resistance to leaf rust under commercial conditions but strains have already been isolated from them in the breeding nursery. While they are still resistant under commercial conditions this situation may not be maintained.

There is reason to believe that the five varieties listed above will give some protection against stem rust for a number of years. Future work will hinge on broadening the genetic base on which their resistance depends by adding further genes to them. These will come from such varieties as Khapstein and from derivations of Agropyron elongatum, which are effective against all local strains of stem rust. A search will be continued for new sources of resistance in the genus Triticum and recent work by Khan (1960) suggests that such are available in T. durum Desf. and can be readily transferred to bread wheats for use in future breeding work.

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Puccinia polysora: A REVIEW OF SOME FACTORS AFFECTING THE EPIPHYTOTIC IN WEST AFRICA

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Introduction

Prior to 1949 Puccinia polysora was a pathogen of little importance and confined in distribution to the Americas and the Caribbean area. During 1949 the rust appeared on Zea mays in Sierra Leone in West Africa and in the following year it became apparent that it was a most destructive and virulent pathogen of local varieties of maize in West Africa. In the following five years it spread to the islands of Mauritius and Réunion in the Indian Ocean, having crossed the African Continent and affected all maize growing areas within the tropical belt (Cammack 1958). Along the West African coast the epiphytotic was very severe in the early stages and often resulted in total crop failure in the humid coastal areas and losses of approximately 30% in the drier, marginal maize growing areas.

When the rust first appeared and was identified as Puccinia polysora there was some doubt whether it had been present in Africa in a weak form prior to 1949, and

suddenly produced a virulent mutant, or whether it was a new introduction. A critical re-examination of World collections of herbarium material of P. polysora by the Commonwealth Mycological Institute and of African material by the writer (Cammack 1959) proved conclusively that the rust was not present in the African Continent before 1949.

The problem thus resolved itself into the study of an aggressive rust in a new environment and the severity of the disease drew attention to factors contributing to the success of the epiphytotic. In the territories of Nigeria and Ghana an extensive study was made of the distribution and severity of the disease in relation to climate, and also of the effects of the environment on development and spread of the rust.

The Distribution of the Rust

On the basis of preliminary observations on rust distribution made in Nigeria it became apparent immediately that there was a gradual decrease in intensity from the humid coastal region northwards towards the drier interior. Within Nigeria there is a wide range of climatic conditions. The coastal fringe has a mean temperature of 80°F, a small annual range of 5°F, a small diurnal range, high average relative humidity, and a high rainfall of 70-120". In the northern fringe of the territory the mean temperature is 82°F with an annual range of 20°F and a very large diurnal range, low average relative humidity, and a rainfall of only 25-35"

In order to obtain a quantitative estimate of the variation in rust intensity a series of assay plots of maize was planted in Ghana, Nigeria, and Cameroons, the sites being chosen to cover all types of environment within the territories concerned. Each assay plot consisted of single rows of twelve varieties of maize covering the full range of susceptibility to P. polysora, interspaced with 'spreader' lines of the highly susceptible variety Lagos White. The plots were assessed quantitatively for rust at four different stages of growth and the plot mean rust intensity determined. On inspection of these results a relationship was apparent between the intensity of rust and prevailing climatic factors, especially temperature, humidity, and precipitation. The results indicated that a large number of climatic factors were involved and eventually vegetation zones (Keay, 1953), expressing the interaction and summation effect of all prevailing climatic factors, were taken as a basis for comparison and it was found that the rust intensities of the several plots within each zone were reasonably uniform and that significant differences in mean rust intensities were obtained between zones.

TABLE 1

Rust Intensity (Quantitative scale 0-4)	Zone
0.0 - 1.0	Sahel & Sudan Savannah
1.0 - 1.9	Guinea Savannah
1.5 - 3.5	Relic Rain Forest
2.5 - 4.0	Lowland Rain Forest
3.4 - 4.0	Mangrove Forest and Coastal Fresh Water Swamp

Rust intensities in relation to vegetation zones in the territories of Nigeria and Ghana.

This survey showed the coastal area to be highly favourable for rust development, and on the basis of the results of the assay the factors favouring the build up of rust in that area were investigated.

Factors Contributing to the Success of the Epiphytotic

(i) The optimum temperature for uredospore germination

At saturated humidity, and in contact with a water surface, uredospore germination was obtained within the temperature range 48 - 92°F with an optimum of 80 - 82°F. At optimum temperature 95% germination can be obtained within 2-3 hours. In the coastal area of Nigeria and part of Ghana this optimum temperature prevails and in addition there is a small diurnal and annual fluctuation from that temperature.

(ii) Temperature requirements for infection of the host

Inoculated maize seedlings subjected to different mean temperatures during the penetration and incubation phases, and at saturated humidity during the penetration phase only, showed mature infection symptoms at different times.

Mean Temperature	Pustule formation (days after inoculation)
75°F	14 days
81°F	9 days
89.5°F	Lesions necrotic and abortive

Quantitatively, pustule formation was best at a mean temperature of 81°F and spore production was highest.

(iii) Humidity requirements for uredospore germination

Saturated humidity is necessary for maximum germination. In vitro tests involved the usual difficulties of accurate control of humidity at near saturation. The only two reliable controls gave the following results:

100.0% R.H.	90 - 95% germination at 77°F
97.45% R.H.	0 - 2% " "

In these experiments the spores were germinated on membranes suspended over the controlling medium. At 100% R.H., moisture condensed on the membrane and the spores were in direct contact with a water surface. At 97.45% R.H., no condensation took place. In the coastal rain forest areas long dew periods exist, providing the saturated humidity and water surface necessary for germination.

(iv) The reproductive capacity of the rust

If any pathogen is to be successful in establishing an epiphytotic within the host population it must possess a high reproductive capacity. An attempt was made to estimate uredospore production by removing spores from selected pustules on potted maize plants using a cyclone spore trap and impacting the spores on to a 0.1% gelatine solution.

After thorough mixing the concentration was determined by a counting slide. With this method it was estimated that one uredosorus on a susceptible variety of host liberates 1,500 - 2,000 spores each day for a period of 18 - 20 days from emergence of the sorus. A resistant variety liberated 600 -1,150 uredospores each day for the same period. On this basis a plant of a rust-susceptible variety of maize naturally infected in the field at the seventh week of growth could discharge 14×10^9 uredospores prior to its death. The rhythm of successive generation of uredosori, only nine days, also contributed to the high reproductive capacity of this rust.

(v) The numerical threshold of infection

In addition to large numbers of inoculum a low numerical threshold is preferable

in establishing a disease in epiphytotic proportions. The results of single spore inoculations on to maize seedlings maintained at optimum conditions for infection showed 1.9% successful infections in some selected rust-resistant varieties and up to 15% in highly susceptible varieties.

(vi) The susceptibility of the host population

Prior to the appearance of P. polysora in West Africa it is known that the rust was confined to the Americas and the Caribbean. The potential host and the pathogen, in respect to West Africa, were, therefore, in isolation, and, as a result, the host possessed no inbred resistance or tolerance. The rust on its arrival in Africa encountered a completely new 'Land Race' of maize.

The factors briefly discussed influence the severity of the epiphytotic. P. polysora was introduced into a new population of Zea mays in a favourable environment. The availability of a highly susceptible host population, the virulence and high reproductive capacity of the pathogen and its ease of dissemination, and the near optimum conditions for spore germination and infection resulted in a typical progressive epiphytotic, which reached its climax in 1953, four years after its introduction and thereafter began to decline.

Factors in the Decline of the Epiphytotic

During recent years the disease has declined in severity owing to several factors.

(a) Disease saturation

The first factor contributing to a decline in severity is the saturation of the host population by the disease. In the early years of the epiphytotic a vigorous system of natural selection of the host was in operation. The most susceptible local varieties in West Africa were so severely attacked that in many instances grain yields were nil. Those varieties which showed a measure of resistance were adopted by the farmer and extensively planted. Without human intervention a limiting level of disease saturation would have been reached in time.

(b) Human selection of the host

The result of natural selection in the first instance followed by human intervention is a reduction in the disease proneness of the host. It was assumed that sources of resistance would be found at the centre of origin of the rust, where it had presumably been present for a long period of time and host-parasite equilibrium had been established. This proved correct and many maize varieties of Central and South American origin were imported into West Africa. Some of these showed a high level of resistance to the local form of P. polysora.

(c) Decrease in virulence of the pathogen

The process of elimination of susceptible varieties of the host by natural selection has been greatly accelerated by plant breeding and the introduction of resistant varieties. The pathogen is consequently confronted with a resistant host population. A result of this is a decrease in the numbers of uredospores produced and the concentration of potential inoculum in the atmosphere is decreasing so that the chance of successful infections is being progressively reduced. In addition to the purely quantitative consideration evidence is available that the rust is undergoing a reduction in qualitative virulence in the respect that repeated inoculations on to standard maize varieties are showing a change in reaction type from the fully susceptible to the intermediate or resistant.

Conclusion

From the observations on the distribution and intensity of Puccinia polysora and on the effects of environment on the uredospore it is evident that this rust is suited to hot and humid tropical conditions, and on the basis of present knowledge it is most unlikely that it will ever constitute a threat to temperate maize growing areas. This is substantiated by the present distribution which is confined to tropical and sub-tropical areas of the world.

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Discussion following paper by D. Mulder & R. L. de Silva

T. E. T. BOND (U.K.) said that one notable feature of phloem necrosis was that even on the most severely affected estates, where the disease had been present for at least 20 years and where roguing of necrotic and unproductive bushes amounted to 5-10% of the total stand at each 5-yearly pruning cycle, it was quite difficult to demonstrate any appreciable decline in yield. These old 'low jat' fields were of highly mixed origin (Dr. Tubbs had shown that half the yield could be contributed by one quarter of the bushes) and it seemed likely that it was the least productive bushes that were becoming diseased. In addition, many of the 'high jat' supplies put in to replace them were coming into bearing. He believed that up to 1945 there were no indubitable records of the disease affecting these supplies; had this desirable state of affairs been maintained?

N. SHANMUGANATHAN (Ceylon) confirmed that this was so.

T. E. T. BOND, continuing, recalled at least one case of a diseased bush in which certain vigorous, unplucked shoots showed successive zones of obviously necrotic and apparently healthy foliage. Propagation by single-node cuttings, however, gave uniformly diseased progeny irrespective of the condition of the parent leaf. He would like to see the effect of alternating periods of high and low temperature on a whole bush, or on individual vigorous unplucked shoots, under controlled experimental conditions.

Discussion following paper by C. J. Magee

J. M. THRESH (U.K.) noted that the procedure for selecting healthy abaca plants in areas devastated by the mosaic disease was similar to that adopted by Posnette in areas of Ghana where the cacao had been devastated by swollen shoot. In that case most of the apparently healthy cacao trees proved to be infected with very mild strains of the virus while others were tolerating infection with virulent isolates. A similar situation could explain the very variable latent period of mosaic in abaca, some plants showing symptoms only when their tolerance breaks down.

C. J. MAGEE said that in the Philippines there are large areas with plantations built up from disease-free stocks. There is a fear that the disease is highly infectious so spraying goes on even in these areas. In reality the disease is not very infectious and it is a pure case of latency.

B. L. CHONA (India) remarked that if a diseased rhizome is planted, some shoots may appear healthy at first but develop symptoms later. Conversely, some may quickly show symptoms which will later disappear.

C. J. MAGEE stated that 3 months after planting 15-20% of the plants show symptoms, and that 6 months and 9 months after planting it is possible to rogue out more. In some cases symptoms are first seen only when the inflorescence appears.

Discussion following paper by J. W. L. Peiris

C. J. MAGEE said that there was no agreement on what constitutes tristeza; Dr. Fraser thought that yellows disease might actually be the tristeza. It strikes citrus of every kind in Australia.

B. L. CHONA (India) agreed that the complex is very difficult. It is hard to define what constitutes decline and stem pitting.

Discussion following papers by F. G. H. Lupton & R. C. F. Macer, I. A. Watson, and R. H. Cammack

A. J. H. CARR (U.K.) said that Dr. Lupton's work, which shows that two factors exhibit recessive resistance to two of the more aggressive physiological races, seems to support Flor's hypothesis of complementary genes in host and parasite.

B. L. CHONA considered that, as a general rule, where the seedling is resistant the adult will be also, but there are exceptions. Seedling resistance tests carried out at 70-85°F may be successful, while at 90°F the plants may be susceptible.

Plant breeding is probably the cheapest way to fight disease, but there are difficulties. Ideally, a variety should be resistant not only to one wheat rust, for some countries suffer from all races of all three. Other diseases may be important and a variety resistant to these may be preferred, and furthermore local preferences of grain quality must be considered. There must be also efficient organisation to ensure the general availability of the desired variety and to keep it pure. The economies of the widespread sowing of resistant varieties must be carefully studied in comparison with those of direct control methods.

July 21 afternoon

Diseases of cacao and black pepper

Chairman: N. F. Robertson

BLACK-POD DISEASE IN GHANA: INCIDENCE OF THE DISEASE IN RELATION TO LEVELS OF PRODUCTIVITY

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West African Cocoa Research Institute, Tafo, Ghana

Summary

Note is made of the type of recording which is necessary to obtain absolute measurements of the incidence of black-pod disease (Phytophthora palmivora (Butl.) Butl.) of cocao in Ghana.

Methods are described whereby data collected by the Cocoa Division of the Ghanaian Ministry of Agriculture have been used to estimate the importance of the disease on cocoa which has shown major increases in yield, following the control of mirid pests.

The results are considered applicable to three-quarters of the cocoa areas in Ghana. The average proportion of pods attacked during the 5-year period, 1954 to 1958, was 28 per cent. and 19 per cent. were completely destroyed. There was a positive and significant linear regression of numbers of black pods on total numbers of pods per acre ($b = 0.252 \pm 0.013$) and there was no difference between the regression coefficients for data collected on plots in Ashanti and Southern Ghana. Further, the slope of the regression lines for each year's data did not differ significantly and was independent of variation in levels of disease between the different years. The proportion of diseased pods did not alter as yields of pods increased. There is a significant correlation between the number of diseased pods in the first and second annual disease outbreaks.

The results suggest that even after mirid pests are controlled the crop, and

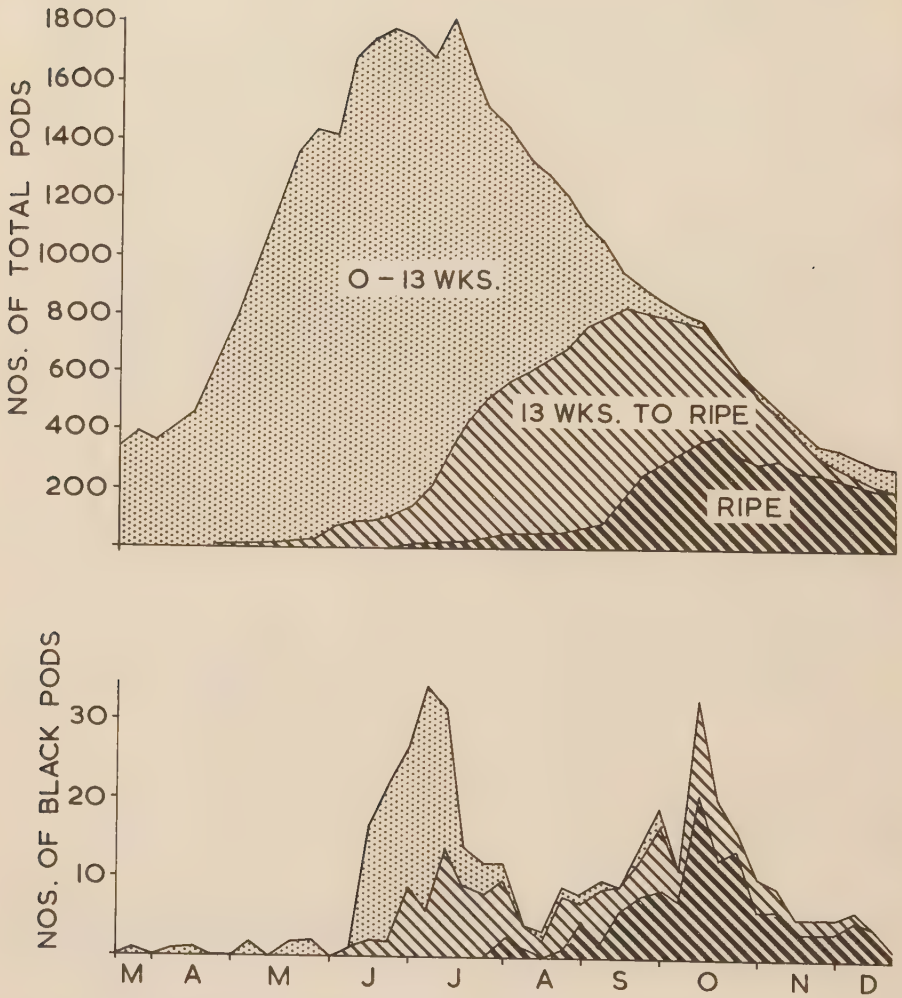

Figure 1. Eiphytotics of black-pod disease in Ghana. See text for description.

numbers of diseased pods, are still not increased to levels which might justify the cost of applying fungicide sprays on peasant-grown cocoa in Ghana.

Introduction

Black-pod disease of cocoa, caused by Phytophthora palmivora (Butl.) Butl. in Nigeria and the Cameroon territories has commonly been recorded attacking more than 50% of the annual crop harvested (Grimaldi, 1954; Thorold, 1953a, 1956, 1959). The disease in Ghana has been considered of far less importance, except in restricted localities where cocoa is grown in river valleys and on the ridges of high scarps. In recent years, the proportion of pods becoming diseased on the control plots of fungicide spraying trials has rarely exceeded 25% and the chemical control methods developed in Nigeria by Thorold (1953a, b, 1956, 1959) have not given economic returns when applied in Ghana (Wharton, 1955-1958, 1958).

It became important to estimate accurately the importance of black-pod on peasant farms in Ghana for two reasons. Firstly, it was not known exactly how representative the losses observed on field trials were; secondly, work started in 1954 by the Ghanaian Ministry of Agriculture on the insecticidal control of mirid pests attacking mature cocoa has given spectacular increases in yield and is now receiving wide application. It was thought that the increased numbers of pods exposed to infection and destroyed might be sufficient to justify the cost of fungicide treatments.

The patterns of seasonal outbreaks

Fig. 1 shows the distribution of black pods, harvested from 200 trees at Tafo during one crop season, in relation to the total numbers of fruits on the trees in any week during the year. The graph of total diseased fruits represents the two outbreaks which occur in Ghana each year. All recorded fruits are split into three age classes in the diagram, and the numbers of infected fruits in each class can be seen in relation to the corresponding numbers of total fruits exposed to infection. It is important to consider the following points from the detailed data represented in Fig. 1 before interpreting results from an extensive field survey.

From 70 to 80 per cent of all fruits below the age of 13 weeks (cherelles) on cocoa trees in Ghana are lost from a physiological wilt during the fruit-setting period of February to July. A cherelle infected by P. palmivora may be completely blackened within two days from the first sign of infection, after which the symptoms are indistinguishable from those of a fruit lost from the physiological wilt. The records of infected cherelles in Fig. 1 were obtained by examining all fruits on the 200 trees on alternate days, and removing all damaged fruits and wilted cherelles as they were recorded. Such a procedure is impossible when recording black pods on large acreages of cocoa, and the usual practice in Ghana and elsewhere has been to restrict observations to fruits which are greater than 3 inches in length (approximately 13 weeks old) and past the stage at which they may wilt.

During the early rains (up to July) infections are largely confined to immature fruits which are completely destroyed. Most of these are diseased cherelles and their occurrence must be appreciated when interpreting large scale records in which they are not included. However, cherelle infections do not necessarily represent a true loss of crop because they occur during the periods of maximum physiological wilt and most of them would have been lost to wilt if not to infection by P. palmivora.

By contrast, most of the pods attacked in the second disease outbreak, from September to November, are ripe (Fig. 1). If these are harvested at intervals of less than one month a large proportion will yield usable beans for the fungus takes some time to grow through the thick pod husk. It is important to measure this proportion in assessing the absolute losses from black-pod disease.

Method of assessing disease incidence and losses

In 1954 one of us (A. L. W.) was associated with the Cocoa Division of the Ghanaian Ministry of Agriculture in the introduction of a standard record sheet

for the classification of harvested crop, and with the training of large numbers of junior staff in the recognition of pod diseases. The record sheet has since been used on nearly all experiments where crop harvesting was a responsibility of the Cocoa Division. An enormous volume of standard crop data has now accumulated from the Cocoa Stations and many types of experimental plots scattered throughout the main cocoa areas. We have used some of this data to determine the importance of black-pod disease in Ghana.

Estimates have been derived from data collected during the 5 years, 1954 to 1959, from 23 'Capsid Yield-Recorded Units' of farmers' cocoa. These are the experimental plots on which the control of mirid (capsid) pests of mature cocoa, by the low-volume application of insecticide sprays, was first demonstrated in West Africa. Figure 2 shows the location of these plots (12 in Ashanti and 11 in Southern Ghana) in relation to the cocoa production (Anon., 1954-59) round the main buying centres, during 1954-59. The plots are chiefly concentrated along the route of the Accra - Kumasi trunk road. They were chosen originally as being representative of mature cocoa (20 to 25 years in bearing) that had been damaged by mirids without reference to the incidence of black-pod disease. They had, however, to be reasonably accessible and do not include any farms on the ridges of high scarps. It was shown first that a frequency histogram of recorded black pods, expressed as a percentage of total pods for each recorded plot in each of the 5 years, fits a normal curve of distribution; hence, the plots form a random sample with respect to the incidence of black-pod disease. Each unit consists of an insecticide sprayed plot (1.3 to 9.6 acres in size) and a control, unsprayed plot of 0.6 to 3.0 acres contiguous with it. One control plot is missing and the total of 45 plots comprise 164 acres of cocoa. The treated plots have been sprayed regularly with insecticide since September 1954, the units are harvested at monthly intervals and all pods over 3 inches in length recorded and classified. The pods

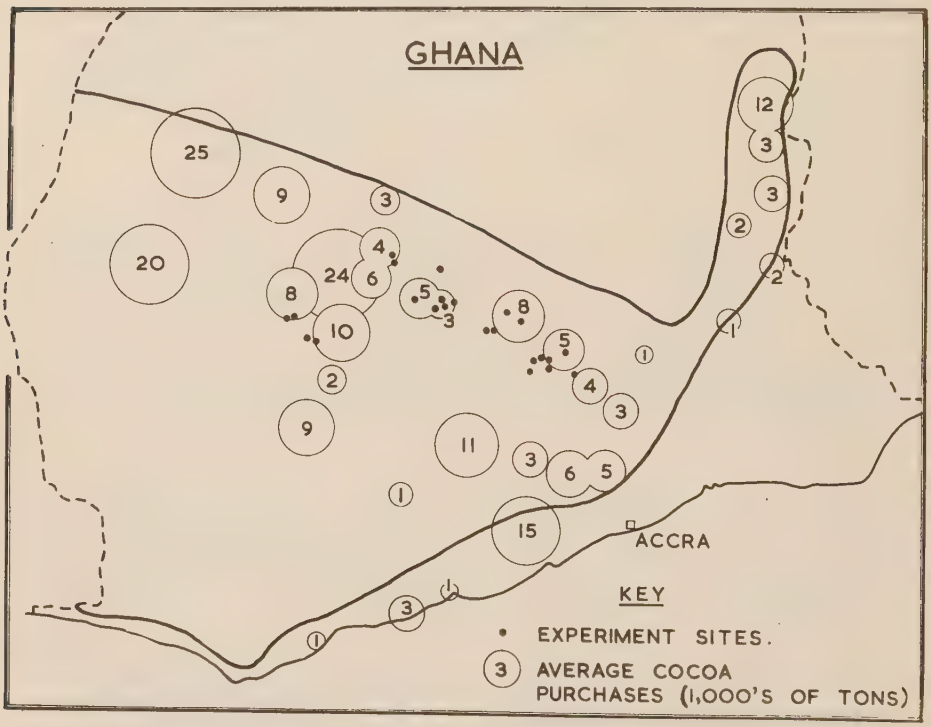

Figure 2. Location of survey units in relation to the average production of cocoa during the period 1954 to 1959

were classified into three groups, healthy ripe, diseased ripe and diseased un-ripe. The proportion of usable beans obtainable from diseased ripe pods was determined during the 1958 season by examining a series of 100-pod samples (11,600) pods in

all). From 37 to 52 per cent. of this category contained undamaged beans, with a mean value of 44 per cent. Aggregate losses from black-pod infection are thus taken to be 56 per cent. of the diseased ripe pods plus all the ones in the diseased un-ripe category. Total pods harvested are the summation of all healthy and diseased pods, excluding pods destroyed by rodent attack, or those damaged by rodents and subsequently infected by a variety of wound-parasites.

Results

Immediate regneration and new growth of sprayed trees followed the initial application of insecticide in 1954, after the fruit of that year's crop had been set. Spray drift and the elimination of mobile mirid pests in the sprayed plots induced a marked improvement of trees in the 'control' plots also. Table 1 shows the average increase in numbers of pods per acre harvested from all the 45 recorded plots, during the 4 crop seasons after 1954. The yield of cocoa on sprayed plots increased from 224 lb. dry cocoa per acre in 1954 to an average of 543 lb. over

TABLE 1

Yields of Dry Cocoa (lbs. per acre)

First year		No. of Years Treated 2	3	4	5	Average
224	Treated	462	568	526	615	543
202	Untreated	325	403	344	352	356

the next four years: (12 pods yield, on average, 1 lb. of dry cocoa). Comparable figures for the 'control' plots were 202 lb. increasing to 356 lb. per acre.

Nearly 4,500,000 pods were harvested and classified during the 5 years. Table 2 shows the distribution of this total over the Eastern Region and Ashanti plots for both the mid- and main-crop periods, and the proportion of diseased pods. An

TABLE 2

Total pods harvested and proportion of diseased pods on 11 plots in Southern Ghana and 12 in Ashanti, over five years

	Total pods (1000's)	Diseased pods as a percentage of total pods Ripe	Unripe	Total
Southern Ghana				
Mid-crop	222	12.7	32.5	45.3
Main-crop	1,553	15.7	11.6	27.3
Total	1,775	15.3	14.2	29.5
Ashanti				
Mid-crop	170	25.8	14.8	40.6
Main-crop	2,479	20.9	3.5	24.4
Total	2,649	21.9	4.3	26.2

average of 30 and 26 per cent. of the total crop was infected on the Eastern Region and Ashanti plots respectively, with an absolute loss of crop of 23 and 16 per cent. when the figures for diseased, ripe pods were adjusted for the proportion which yielded healthy beans. More crop was lost in the Eastern Region because the proportion of diseased, unripe pods was much higher.

Because of the increases in total pods following mirid control, and the differences

in yield between plots, it is possible to examine the relationship between the numbers of black pods per acre and the total numbers of pods per acre exposed to infection. Thorold (1952, 1953a), from counts of pods on single trees, has already shown in Nigeria that the numbers of black pods per tree tends to vary directly with the numbers of total pods per tree. Figure 3 shows a regression line fitted to a scatter diagram of numbers of black pods plotted against total pods, for every recorded plot in each of the 5 years. The value of the regression coefficient, $b = 0.252 \pm 0.013$ ($p = <0.001$), shows that for every increase of difference of 1000 pods 250 might be expected to become infected by the black-pod fungus. There was

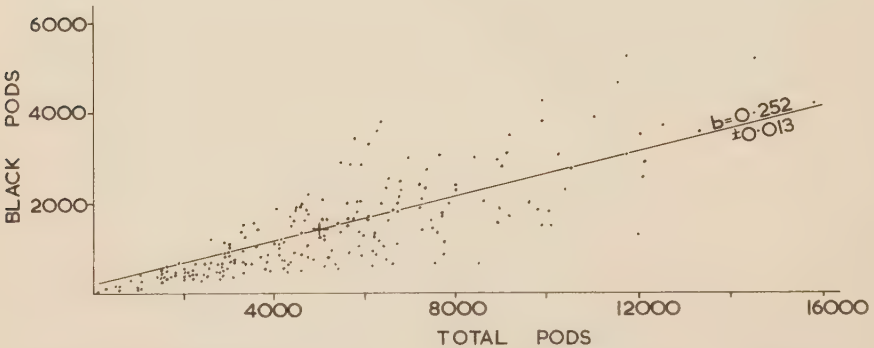

Figure 3. Relationship between numbers of black pods per acre for unit increases in total numbers of pods per acre.

no significant difference between the coefficients obtained when data from the Southern Ghana and Ashanti plots were treated separately ($b = 0.28 \pm 0.026$ and $b = 0.23 \pm 0.014$ respectively). Further, the slope of the regression lines for individual years did not vary significantly, and the regression coefficients were independent of variation in levels of disease between the different years (Figure 4). Figure 4 also illustrates the high levels of disease in 1957, when black-pod disease was especially serious in West Africa, compared with the other extreme in 1958 when levels were relatively low.

The survey data showed a significant positive correlation between the number of diseased pods in the first 'black-pod' outbreak during May, June and July and those in the outbreak on the season's main crop during September to November ($r = 0.38$, $t = 5.29$ with 168 d.f.). This may be an important factor in reducing the cost of fungicide control measures if spray applications concentrated only on the first outbreak reduced sources of inoculum sufficiently to prevent the development of a large outbreak on the main-crop pods.

Discussion

The results from the 'Capsid Yield-Recorded Units' are not now entirely representative of all the farmers' cocoa in Ghana. Since the plots were laid down there has been an enormous increase in crop production from new plantings in the North West region of Ashanti, which in 1958/59 yielded one-quarter of Ghana's total crop (Figure 2). The incidence of black-pod disease is probably less in this area where the rainfall is lower than the 60 to 70 inches per annum precipitation received in the areas of older cocoa. Production in the Eastern Region of Southern Ghana is increasing, despite the continued devastation from Cacao Swollen Shoot Virus disease, but at the end of 1959 the results above apply to three-quarters of the main cocoa producing areas, that is, those situated in the 60 to 70 inches per annum rainfall belt.

The estimates of disease incidence and losses are conservative if in fact infections of cherelles represent a direct loss of crop. However, if physiological wilt is a mechanism whereby cocoa trees adjust their final yield to their supply of nutrients and other environmental factors, then it might be expected that the numbers of fruits wilting would be adjusted in response to cherelle losses caused by other factors. Conversely, from the practical view of disease control measures,

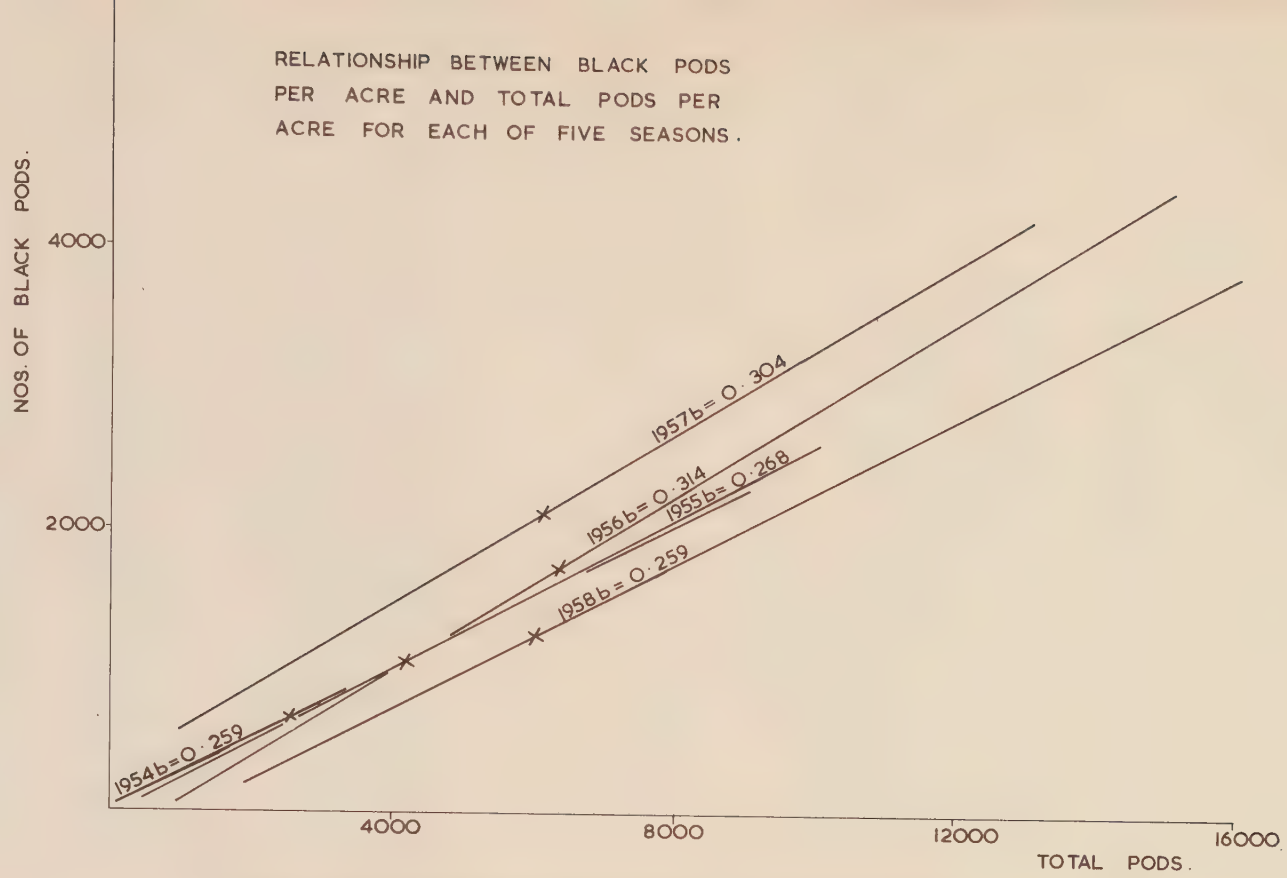

Figure 4. Relationship between black pods per acre and total pods per acre for each of five seasons.

cherelles protected from disease infection may instead wilt and not develop to maturity. Until these problems are clarified the importance of cherelle infections on cocoa trees in Ghana cannot be determined.

There was no evidence, from calculated regression coefficients, to suggest that the proportion of diseased pods alters as levels of yield increase, using either the whole data or that from plots giving yields of over 500 lbs. dry cocoa per acre. This is in agreement with the finding of Thorold (1956) that 'black-pod' percentages appear to be independent of total pod numbers when black pods are removed infrequently. The survey results can, therefore, be applied to yields of up to about 1000 lb. per acre (12,000 pods) which is surpassed by 8 of the 45 recorded plots. It cannot be definitely known, until a source of data becomes available, whether 'black-pod' percentages will decrease in Ghana with very large yields, as suggested by Reynaud (1953) or increase, for which Thorold (1956) has found evidence in Nigeria.

There appears to be no reason why the average yields from farmers' cocoa in Ghana should not be increased from a level of 200 to 250 lb. dry cocoa per acre to a conservative 500 lb. by the efficient control of mirid pests, regular harvesting and the improved management which the 'Capsid Yield-Recorded Units' have received. However, even at this level of yield the numbers of diseased pods to be expected are still probably insufficient to justify the application of fungicide sprays. Table 3 shows the monetary value of average crop losses to be expected from one acre of cocoa in the areas surveyed, at the price paid to the farmer (£112 per ton of dry cocoa) and at an estimated price received by the Ghana Cocoa Marketing Board on the world market (£250 per ton). The value of these losses can be compared with the cost of £8.8 per acre per annum for applications of 1.7 per cent.

TABLE 3

Value (£'s) of average crop losses due to black-pod disease, from trees yielding 500 lb. dry cocoa per acre on 11 plots in Southern Ghana and 12 in Ashanti, over five years

Price per ton dry cocoa	Region		
	Southern Ghana	Ashanti	Average
£112	5.3	3.7	4.4
£250	12.7	8.2	9.6

Perenox applied by power-sprayers in Nigeria (Thorold, 1959) and £7.8 per acre for the same treatment on a 7-acre plot at Tafo, Ghana (Plantation Manager's records, W.A.C.R.I.). These costs do not include the capital cost of power-sprayers but in Ghana these are being purchased on a huge scale by farmers for mirid-control and would be available for applying fungicides. In 1960 it is proposed to examine again the economics of spraying against black-pod disease on 16 of the survey units which are expected to give a minimum yield of 450 lb. per acre and are subject to a pod disease incidence of at least 20 per cent. of the total pods harvested.

Acknowledgements

Staff of the Cocoa Division of the Ghanaian Ministry of Agriculture placed their crop records freely at our disposal. In particular we would thank Mr. G. Burge, Agricultural Survey Officer, for his advice on details of the 'Capsid Yield-Recorded Units' and for his collection of an excellent set of records.

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STRAINS OF Phytophthora palmivora (BUTL.) BUTL. OCCURRING IN WEST AFRICA

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Summary

In association with the programme of selection and breeding cocoa types for resistance and tolerance to black pod disease, examination of 179 cultures of Phytophthora palmivora (Butl.) Butl. from ten different cocoa-producing countries in West Africa showed the presence of distinct strains of the pathogen occurring on cocoa. The two more important strains were sexually complementary and belonged to the 'cacao' and 'rubber' groups of the fungus. A third, small group of isolates resembled the 'atypical' description for the species in several respects and was complementary to neither of the other strains.

The strains were found to differ in their geographical distribution; isolates from Ghana, Ivory Coast and the majority from Sierra Leone all belonged to the 'cacao' group, and occasional isolates of this group were found outside this, more westerly, region. In countries lying east of Dahomey, Nigeria, Southern Cameroons Fernando Po, and Cameroun, isolates of the 'rubber' group were dominant. A limited number of disease samples from Gabon, Belgian Congo and Angola were also examined; these contained isolates falling into all three major groups, but more cultures are required to typify the pathogen in these countries.

Isolates of the 'cacao' group were the more virulent in experiments with detached cocoa pods. Marked differences were found between strains in appearance and rate of lesion development in pods and in artifical culture, in sporangial dimensions and in oospore production. In nearly 900 mixed cultures of the isolates oospores were produced in all cultures containing the 'cacao' and 'rubber ' groups, and rarely in mixed cultures of the 'rubber' group. Presence of complementary strains may be important in the selection of resistant cocao types and in chemical control measures

and may warrant changes in phytosanitary procedure in West Africa. Comparison of West African isolates with cultures from other countries showed the 'cacao' group isolates, the dominant type of the pathogen on cocoa, to be very similar, but the 'rubber' group isolates were unlike those of the same group from other parts of the world. Occurrence of different strains on cocoa alone has shown the need for a new method of describing the various types.

[The full paper has appeared in Trans. Brit. mycol. Soc. 43:665, 1960]

A GALL DISEASE OF COCOA (Theobroma cacao L.) IN GHANA

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Summary

The "buba" or cushion gall disease of cocoa has been reported in Trinidad, British Guiana, Surinam, and 10 South and Central American countries.

Galls which resemble so-called "green-point" cushion galls on cocoa in the Western Hemisphere have been known on West African Amelonado cocoa in Ghana since 1923. In a survey, only 44 trees affected with the West African gall disease were found in approximately half-a-million acres of Ghanaian cocoa surveyed. Sixteen infected trees were widely distributed throughout the cocoa-growing areas, 8 were collected from one farm, and the remaining 20 were found on one small farm. Galls were found on both Amelonado and Amazon cocoa, but none was found on trees grown from imported vegetative material. It is concluded that the disease has not been introduced recently into Ghana, but is probably indigenous to West Africa.

The West African gall disease has been transmitted from galls on mature trees and on seedlings artificially infected by various methods. It has been shown that cocoa half-beans are very susceptible to infection and, since primary seedling galls usually develop within 4 weeks of inoculation, have been used as test plants in transmission studies. Although the field survey has shown that the gall disease is at present of little economic importance in Ghana, the ease with which the disease has been transmitted in laboratory tests and the similarity of its galls with those of the important cushion gall disease in the Western Hemisphere indicate that it should be considered a disease of potential importance. For this reason it has been recommended that all galls found on cocoa should be removed and destroyed by burning.

Gall-like cushions observed on some "male" trees and very old trees of Trinitario and Cundeamor origin are anatomically different and are not considered to be a symptom of the gall disease.

Neither nematodes nor other gall-forming pests have been found in gall-tissue and transmission of the disease by mechanical methods in the absence of such pests indicated that the disease is caused by a pathogen. Fungal hyphae have been observed in some stained sections of galls, but in preliminary tests only Botryodiplodia theobromae and Calonectria rigidiuscula were isolated occasionally from gall tissue. Graft and insect transmission tests have failed to demonstrate systemic infection, the pathogen failed to pass through a Seitz filter and no infectivity could be detected in supernatants after brief low-speed centrifugation of infective gall extracts. These results suggest that the disease does not result from virus infection and attempts to isolate a bacterial or fungal pathogen are in progress.

INTRODUCTION

The "buba" or cushion gall disease of cacao was first observed in 1938 in Valle and Antioquia, Colombia, (Garces, 1940) and has been reported subsequently in British Guiana (Bates personal communication), Surinam (Van Suchtelen, 1955; Hutchins, 1958a), Trinidad, and 10 South and Central American countries

(Kevorkian, 1951; Losada, 1955; Hutchins, 1959; Hutchins, Siller and Hansen, 1959). Infection is reported to cause hyperplasia and, eventually, sterility of affected floral cushions and the disease is causing much concern in areas of western Nicaragua, northern Colombia, and eastern Nicaragua where it is widespread (Hutchins 1958 a & b).

Galls similar in appearance to the "green-point" type of cushion gall in the Western Hemisphere (Hutchins, Desrosiers & Martin, 1959) have been known in Ghana since 1923 (Dade, 1926). After epiphytotics of the cushion gall disease in Nicaragua, Colombia, and Costa Rica had been reported (Hutchins, loc. cit.), a survey was made in Ghana to assess the importance of the apparently similar West African gall disease and, concurrently, attempts were made to determine its cause. We report here the results of this survey, the symptoms and transmission of the West African disease, and preliminary attempts to determine its etiology.

RESULTS OF THE FIELD SURVEY

To determine the importance of the West African disease in Ghana a survey was made with the collaboration of the Division of Agriculture from August, 1958 to August, 1959. Before the survey commenced photographs of a typical gall (fig. 2) were distributed to Regional offices of the Division of Agriculture and these were then shown to all field staff of agricultural extension service spraying gangs and swollen shoot disease-control teams. When galls were found by these field workers the infected trees were inspected by the authors or, when this was not possible, galls were sent to the West African Cocoa Research Institute for examination.

In this 12-month survey, during which it is estimated that approximately half-a-million of the four million acres of cocoa in Ghana was inspected , only 44 gall-bearing trees were found (see Table 1 and fig. 1). Sixteen trees were widely

Fig. 1. Distribution of gall-bearing trees found in Ghana between August, 1958 and August, 1959

TABLE 1

Distribution of gall-bearing trees found in Ghana from August, 1958 to August, 1959

Region	Area	No. of trees
Eastern	Tafo	1
	Nankese	4
	Kofi Pare	1
	Adidiso	1
	Adonkwanta	2
	Maase	20
Ashanti	Goaso	2
	Ankasi	1
Western	Wiowso	8
	Wiawso	2 (on T62)
	Assin Prasu	1
	Assin Foso	1 (on T63)
	Total	44

distributed in cocoa-growing areas, 8 were found in a small farm (0.7 acres) at Maase in the Eastern Region of Southern Ghana (Wharton & Brunt, 1959). Three galls were collected from 1 tree at Maase, 2 galls were found on a tree at Nankese, but a single gall was collected from each of the remaining 42 trees.

Galls similar to that shown in fig. 2 were found on chupons, trunks, and fan branches of saplings and trees of both Amelonado and Amazon (cultivars T62 and T63) cocoa, but none was found on trees grown from imported vegetative material.

All galls found in Ghana were morphologically similar to the type described in the Western Hemisphere as "green-point" cushion galls: "flowery" galls (Hutchins, Desrosiers & Martin, 1959) were never observed. Galls were roughly hemispherical in shape and varied in size from 1 to 13 cms. in diameter. They were firmly attached to trees by a short central stalk but, unlike galls in Central and Southern America, could not be easily detached. Examinations of stained serial sections of galls showed that they consisted of a compressed branch system bearing a large number of small green buds. Dead galls were frequently collected from trees and these were hard and woody with a black crumbly surface.

Enlarged gall-like cushions (fig. 3) which superficially resembled galls were found on some so-called "male" cocoa trees and old trees of Trinitario and Cuneamor origin. However, unlike true galls, swollen cushions on these trees were composed of spongy parenchymatous tissue without internal branches and they did not possess a central stalk.

Figure 2
A typical gall from an infected cocoa tree

Figure 3
Enlarged gall-like cushions on a "male" cocoa tree

TRANSMISSION OF DISEASE

Mechanical transmission

The disease has been transmitted by rubbing half beans with macerated tree and seedling gall tissue and by stroking half beans with a moistened squirrel hair brush which has previously been in contact with galls (table II). Attempts to transmit the disorder of "male" trees by these methods failed.

TABLE II

Rates of transmission by mechanical methods.

INOCULATION SOURCE	Macerated Gall tissue	Moist contaminated brush	Total
Tree Galls	8/50	9/18	17/68
Primary seedling galls	5/85, 10/10	13/100	28/195
Secondary seedling galls	4/10	6/20	10/30
Enlarge cushions of tree	0/20, 0/20	0/10	0/50

Numerator indicates the number of infec ted plants and the denominator the number of plants inoculated.

Half beans of West African Amelonado cocoa were usually used as test plants, but it has been demonstrated that beans from open-pollinated pods of Amazon, Trinitario, and Criollo female parentage are also susceptible to infection. The transmission results obtained by inoculating half beans from these pods with macerated gall tissue from infected Amelonado seedlings are shown in Table III.

TABLE III

Mechanical transmission to Amazon, Criollo, Trinitario and Amelonado half-beans

COCOA SELECTION		1st Test	2nd Test	Total
Amazon	T16	3/15	0/13	3/28
	T2	4/15	2/13	6/28
Trinitario	ICS 1/738	14/15	6/13	20/28
	ICS 89/106	7/10	.	7/10
	ICS 8/109	6/10	.	6/10
	ICS 25/119	7/10	.	7/10
Criollo	194/24	8/10	.	8/10
	195/182	4/10	.	4/10
Amelonado		10/10	4/10	14/20

Numerator indicates the number of infected plants and the denominator the number of plants inoculated.

Insect Transmission

The disease has been transmitted also by young adults of Pseudococcus njalensis Laing. The insects were removed from seedling galls with one brush, transferred to Petri dishes with sterile brushes and then transferred with other sterile brushes to half-beans at the rate of 7 per test plant. Five of 11 inoculated test plants subsequently produced galls.

Attempts to transmit the disorder of "male" trees to 20 half beans using P. njalensis failed.

SEEDLING GALLS

Primary galls produced on seedlings after insect and mechanical inoculation of half beans first appear as an enlargement of the bud in the axil of the attached cotyledon. Two additional buds soon arise from its base (fig. 4) and the gall increases in size as a result of continued bud proliferation. The size to which seedling galls grow varies considerably but some of the largest were 2 cms. in diameter three months after inoculation of the test bean (fig. 5). When half-beans were inoculated, primary galls usually developed only in the axil of the attached cotyledon, but when whole beans were used a gall frequently developed in the axil of each. Seedling galls, like tree galls, appear to consist of a compressed branch system, bearing numerous small green buds.

Secondary galls, which have the same structure as primary galls, have developed in the axil of the first leaf or first pair of leaves (fig. 6) on some inoculated seedlings which had previously produced primary galls.

Fig. 4. Primary galls developing at the cotyledonary node of a cocoa seedling after inoculation of the half-beans.

Fig. 5. A primary seedling gall at the cotyledonary node two months after half-bean inoculation.

Fig. 6. A secondary gall on an artificially-infected cocoa seedling.

ETIOLOGY

No gall-forming pests (P. F. Entwistle, personal communication) or nematodes (E. Dunn, personal communication) were found in galls or adjacent tissues of infected trees and seedlings. Fungal hyphae have been observed in some stained sections of galls, but only Botryodiplodia theobromae Pat. and Calonectria rigidiuscula (Berk. & Br.) Sacc. were isolated occasionally from gall tissue.

Attempts to demonstrate systemic infection in gall-bearing trees and seedlings by graft and insect transmission tests consistently failed. Thus young adults (10 per test bean) of P. njalensis failed to transmit the disease from stem pieces of infected trees in 28 tests, and from the apices of young seedlings with primary galls in 4 tests. Moreover, none of 10 one-year-old seedlings have developed galls sixteen months after each had been grafted with 2 bark "patches" from an infected tree. Similarly the disease has not been graft-transmitted to 27 young seedlings using bark "patches" (2 per test plant) taken from the stem between primary and secondary galls of infected seedlings.

When young seedling galls were macerated in a small volume of sterile water and the extract then passed through a Seitz filter (Grade EKS sterilising asbestos film, Griffin & George Ltd.) the filtrate was non-infective. When in another experiment similar gall extracts were centrifuged for 10 minutes at 7,000 r.p.m. and the supernatent and precipitate then assayed for infectivity only the latter was found to be infective.

These results indicated that the disease does not result from virus infection. Initial attempts in West Africa to isolate a pathogen from cocoa galls failed. Later, bacterial cultures resembling Agrobacterium tumefaciens (Smith & Townsend) Conn. were isolated from cocoa galls sent to the Commonwealth Mycological Institute, but none was shown to be pathogenic when inoculated on to cocoa half beans. Forty half beans were inoculated also with an authentic culture of A. tumefaciens (National Collection of Plant Pathogenic Bacteria, No. 397; A. C. Braun's strain B6). No galls were produced on seedlings but tumours up to 1 cm. in diameter developed on all the inoculated beans (fig. 7).

Fig. 7. Outgrowth on cocoa half-bean induced by Agrobacterium tumefaciens (Smith & Townsend) Conn.

Since preliminary attempts to isolate the pathogen from cocoa galls failed some herbaceous plants were inoculated with infective gall extracts by rubbing and needle puncture to determine whether they were susceptible to infection and would produce galls from which the pathogen could be isolated more readily. No galls were produced on inoculated seedlings of Helianthus annuus L., Mangifera indica L., Nicotiana glutinosa L., Petunia hybrida Vilm., Phaseolus vulgaris L. (cultivar Canadian Wonder Improved) and Vinca rosea L.

Discussion

The results of the field survey show that the West African gall disease is at present of little economic importance in Ghana. However, the ease with which it has been transmitted in laboratory experiments and its close resemblance to the very important disease in the Western Hemisphere indicate that it should be considered a disease of potential importance. The Ministries of Agriculture in Ghana and nearby countries have been advised that all galls found on trees should be removed and destroyed by burning. There is, however, no immediate cause of alarm since the disease is not more widespread now than it was 37 years ago. Galls on cocoa have been known in Ghana since 1923, affected trees found in our survey were widely distributed and none was found on trees grown from imported vegetative material. The disease is, therefore, thought to be indigenous to West Africa. Removal of galls is unlikely to result in the complete eradication of the disease, but should prevent the local spread of infection which has apparently occurred at Maase and Wiowso.

Enlarged gall-like cushions observed in Ghana on so-called "male" and old trees of Cundeamor and Trinitario origin, although superficially similar to true galls, are anatomically different. Since attempts to transmit this disorder using the same methods with which the gall disease was consistently transmitted failed, swollen cushions on these trees are not considered to be symptoms of the gall disease.

Since the disease has been transmitted readily in laboratory experiments by mealybugs and by mechanical inoculation, it is surprising that spread of infection has been detected in 2 farms only. It is possible that cocoa half beans are more susceptible to infection than older plants and that the results of laboratory experiments in which beans are used as test plants do not indicate what occurs naturally in the field. The factors affecting the spread of the disease in the field have not been investigated and the cause of the failure of epiphytotics to develop is unknown.

It is of interest that the disease has been transmitted by P. njalensis which is the principle vector of the cacao swollen shoot and cacao mottle leaf viruses in Ghana. It is not yet known how transmission is affected by this mealybug species or whether other insects or pests will transmit the disease.

In early experiments cocoa half beans were shown to be very susceptible to infection with the gall disease; since primary seedling galls usually develop within 4 weeks of bean inoculation, half beans have been used as test plants in transmission studies and for testing the pathogenicity of bacteria and fungi isolated from gall tissue.

The development of secondary galls on some infected cocoa seedlings is difficult to explain since systemic infection in such seedlings could not be detected in graft and insect transmission tests. This situation is similar to that in which secondary galls are produced in an unknown manner on certain plant species when infected with the crown gall bacterium, A. tumefaciens (Braun & White, 1943).

Cushion gall disease in South and Central America has been attributed to virus-infection (Kevorkian, 1951), to eryiophyid mites (Losada, 1955) and it has been suggested also that the disorder is inherited, results from mineral deficiency or toxicity, or is induced by bacterial or fungal infection (Wellman and Orellana 1954). Transmission of the West African disease by mechanical methods in the absence of insects and other pests indicates that it is caused by a pathogen. No evidence has been obtained to suggest that the disease results from virus-infection. Although the bacteria and fungi which have been isolated so far from gall tissue have not been shown to be pathogenic, attempts to isolate the pathogen are continuing.

The diseases in West Africa and the Western Hemisphere are characterised by similar symptoms in the same host and it is possible that they have the same or similar cause. As this has yet to be demonstrated we have referred to that occurring in Ghana as the West African gall disease.

Acknowledgements

We wish to thank Messrs. E. Dunn and P. F. Entwistle of the West African Cocoa Research Institute for demonstrating that eelworms and gall-forming pests did not occur in galls. Dr. A. Hayward of the Commonwealth Mycological Institute kindly supplied the authentic culture of A. tumefaciens .

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A ROOT DISEASE OF BLACK PEPPER IN SARAWAK

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Summary.

A serious outbreak of a root disease of black pepper in Sarawak in 1952-53 was found to have been caused by a species of Phytophthora. No oospores have been found. The disease is almost certainly the same as foot rot whose etiology was determined in Indonesia in the 1930's and where it was found to be widespread.

Infection can lead to the destruction of an acre holding, 700-800 vines, in 4-5 months. The pathogen is possibly a soil inhabitant with a quickly declining saprophytic phase. Changes in the traditional husbandry, which favours the spread of a soil pathogen with water borne spores, would help in controlling the disease. There are indications that resistant types of black pepper may be found.

In 1952, a destructive unknown wilt of black pepper (Piper nigrum L.) began to cause alarm in Sarawak. This is a brief outline of some of the work done with W. P. Mowat (now at the Scottish Horticultural Research Institute) since mid 1956. A Phytophthora sp. was isolated and found to be the pathogen (Holliday and Mowat, 1957). The disease is called foot rot following Muller (1936), who described what is almost certainly the same disease in Indonesia. Reports of wilts of this plant from India, Indonesia, Sarawak, and the Indo-China region are many and begin about 50 years ago. But only Muller convincingly demonstrated a pathogen which he called Phytophthora palmivora var. piperis.

The Host

In Borneo, black pepper has probably been grown for nearly 300 years. It is cultivated by Chinese small-holders on traditional lines as a cash crop. The vines are grown on mounds without shade and to a height of 10 ft. up dead, hardwood posts. Strict pruning ensures regular development of the lateral fruiting branches, and results in a bushy columnar canopy. Spacing is 7-8 ft. on the square. First yields come in the 3rd year, when the vine reaches the top of the post; and a fair annual crop from a mature plant is 10 lb. of marketable black pepper. An average peasant holding has 750 vines. The life of a vine is 10-15 years and the method implies a long term shifting cultivation through primary forest, the main fertilizer being burnt earth made from top soil and organic debris. Land rights and legislation now prevent this and almost all post-war plantings have been on land which has reverted to secondary vegetation. Organic fertilisers are preferred, but manuring is often unsatisfactory. Only cuttings are used and gardens are virtually clonal. Sloping land of the yellow, latosol group of soils is generally chosen. Clean weeding between and on mounds is always done and the lower lateral branches allowed to trail on the ground. The underground parts of a mature vine consist of a stem piece of 4-7 rooting nodes, 40-50 cm. long and 5-8 cm. diameter. The main roots arising from this are up to 2 cm. diameter and penetrate 4-6 feet. The feeding root network is restricted to the fertilised mound which, when well formed, is about 4 ft. across and 1 ft. high. Infection by Meloidogyne javanica is common. What part, if any, the eelworm plays in the etiology of foot rot is not yet known.

Symptoms

First above-ground symptoms are a slight droop in the foliage followed by a dulling in colour. Before all the leaves become chlorotic or develop necrotic tips and petioles they begin to fall uniformly from the whole vine. Later, the spikes drop and the lateral branches become necrotic and disarticulate at the nodes. Most collapsing vines reach the $\frac{3}{4}$ leaf-fall stage in 8-10 days.

The underground stem of a wilting vine has a deep black, characteristic lesion sharply outlined against the yellowish, healthy, outer wood. Some distance behind this juncture the outer tissues have disintegrated, exposing the lignified elements which appear as ribbon-like strips. Rotting results in decomposition products and bacteria entering the vessels. This shows as a vascular discolouration which can be seen well in advance of the juncture in the outer wood.

The Pathogen

Isolations of the Phytophthora are readily made from the necrotic edge in the underground stem and main roots. After sterilising in calcium hypochlorite and plating to plain agar the typical hyphae emerge through the bacterial ring in 1-3 days. From an active lesion the fungus will grow out vigorously in pure culture. The fungal followers are commonly Fusarium solani, Rhizoctonia sp., and Botryodiplodia theobromae. Pythium splendens occurs, but only from minor roots.

The Phytophthora is invariably associated with typical symptoms, and isolations have come from 54 different holdings in scattered parts of the country. The pathogen can also be recovered from lesions on rootlets (± 1 mm. diam.), leaves, and spikes before there are any underground stem symptoms. Using wounded apples it has been baited from soil debris.

Pieces of agar culture or infected host tissue develop sporangia when placed in petri solution. The sporangiophore is simple and lax without proliferation. The sporangia are ovoid to obpyriform, strongly papillate, and not easily detached. The are usually 40-50 × 25-30μ. Chlamydospores seem infrequent in culture and attempts to induce fusion organs or to find them in nature have so far failed. Dense growth occurs on oatmeal agar, but sporangia are not abundant until the mycelium is in contact with a nutrient liquid film. Zoospores emerge singly on a drop of temperature to 20° - 22°C or below.

Colonization of the Host

Observations suggest that natural infection begins in the minor roots, infection spreading centripetally. Main roots become infected in turn and stem penetration results. Minor root isolations from apparently healthy vines indicate an incubation time of 15-85 days (mean 35) before wilt begins. Artificial inoculation with liquid culture suspensions poured on to the mound surface gave times of 9 - 68 days (mean 42).

Point inoculations with massive agar inocula on main roots of 5-year old vines revealed stem resistance to invasion. When one root was inoculated stem penetration occurred in 3 out of 9 vines. When 2 and 4 roots were inoculated, penetration took place in 5 and 7 vines, respectively, out of 9 in each category. The undamaged stems and major roots are most probably highly resistant to natural attack. Young field plants are also susceptible. Root inoculations on forty 10-month old vines produced wilt and death in 21 of them.

The stem having been penetrated through some main roots the advancing edge of the fungal rot may spread from it into previously healthy roots. A centrifugal rot of a further part of the root system thus develops. The advance of the stem lesion ceases at about ground level except under exceptionally favourable conditions, when it may spread up the main stems which climb the supporting post. Leaves, flowers, and berries are susceptible. This kind of infection, as Muller pointed out, comes about probably by splash. Infected lower leaves were found after field vines had been inoculated with watery suspensions. A count of 140 leaves with lesions in one garden (± 60 vines) showed that 37% occurred within 3 cm. of soil level and 40% within 15 cm. Natural symptoms have all been reproduced by artificial inoculations.

Epidemiology

Leaf symptoms are possibly the first above ground sign that a garden is infected, but shortly afterwards wilt will appear. The onset of collapse can be extremely rapid. In one stand of 1,044 vines defoliation increased from 8% to 80% in 4 months. In 40 cases of foot rot, wilt began in 30 of them at a low point in the topography of the holding. Apparent spread from such a centre is centrifugal but soon afterwards scattered outbreaks may occur in other parts of the garden from which, in turn, wilting spreads outwards. There is little doubt that the cultivator, during his continual clean weeding and other operations, spreads inoculum from the original infective site, perhaps a single plant, where it has built up. A demonstration of how infective contaminated soil can become was involuntarily given by one owner who dropped his healthy, fresh prunings from the top of his plants on to the ground. Before these had wilted Phytophthora lesions were seen on the leaves.

Once a garden is attacked most the of vines usually become infected. But when spread is slower than usual and the gardener begins to neglect his holding, i.e. stops weeding, spread may cease altogether. This was noted by Muller, who suggested that the consequent impeding of free water flow over the bare soil and cessation of soil movement in cultural operations were among possible explanations. Muller also found that the first cases of foot rot occurred along paths running through the holdings and at entrances to them. Some outbreaks in Sarawak fit this observation.

There is no regular season of the year which would be significantly unfavourable to the fungus. Sarawak has two monsoons, a rainfall of 100-200 ins. a year, and no well defined dry period. There seems, therefore, to be no marked seasonal effect on incidence although isolation on the agar plate is more successful during the wetter months.

Status of the Pathogen

Glass tapes permeated with mycelium and placed in tumblers with unsterilised soil of known moisture content were tested for viability at intervals, using pepper seedling bait. They were also examined microscopically. Even under favourable moisture conditions survival could not be detected after 2 weeks. Whether or not the fungus can be classed as a relatively unspecialised parasite in the soil inhabitant group (sensu Garrett 1956), its saprophytic survival in massive host tissue is of interest. The duration of such survival for a root inhabitant depends in part on the volume of infected tissue (Garrett loc. cit.) Naturally infected underground stems were recorded, left in situ and grouped by time from initial infection. They were then removed altogether and placed in large pots without disturbing the roots of pepper cuttings already established as bait. Survival falls off after 2-3 weeks from infection, but it has been detected at a low level after 14-16 weeks.

Field evidence on survival is sketchy. One site was replanted one year after the disease had been reported active. In another, cuttings were set 12 weeks after the stems of dying vines had been ploughed in. Both sites, 4 years later, are still free from natural wilt. Foot rot has never been found to be serious in young gardens up to 2 years old. Even single infected vines in such young gardens have been extremely rarely found. Older gardens up to about 9 years occur which remain healthy. No attempts have yet been made to detect the fungus in these gardens. Such evidence as there is - and assuming that the primary host is the obvious bait - indicates that conditions for infection do not always exist.

Assuming the absence or rarity of oospores, how do we explain survival in the absence of the host? It seems necessary to be able to do this but data is inadequate. Little alternate host substrate study has been done. Muller's isolates could infect a number of cultivated plants; none of them seemed to be true parasites on any host except pepper. Hickman (1958) has referred to the paucity of data on the saprophytic development on soil-borne Phytophthora but has drawn attention to the evidence that it does occur. The declining saprophytic phase (Garrett loc. cit.) seems rapid in this disease. To account for survival, at a low level, we might introduce the concept of 'non-preferred' hosts for soil pathogens (Stover, 1959). Stover suggests that monoculture favours selection of pathogenic clones adapted to saprophytic survival. This, together with the necessary build up on the primary host before 'disease' appeared, would account for the general phenomenon of slight disease in the first year in virgin soil. But in foot rot it seems necessary to postulate an additional factor where build up on the 'preferred' host occurs only after introduction of small inocula into cultivated areas.

The idea of a distinct saprophytic or 'non-preferred' host phase fits an omnivorous tropical fungus like Phytophthora palmivora. Tucker (1933) lists 59 species of flowering plants, in 22 families, as hosts. Some forms of this fungus are clearly soil organisms. The extensive inoculation work with it suggests that its saprophytic ability is well established. It may be said to exist, assuming its validity as one species, as parasitic, physiologic strains, each of which have only one or few related primary or 'preferred' hosts. But these strains are adapted to infect a wider host range provided the plant tissue is wounded, weakened, or already decaying. Thus the inoculation test on the healthy host shows the strain in its destructive, specialised, and parasitic phase; whilst its broader and 'hidden' saprophytic phase is indicated by its ability to infect many more unrelated hosts whose natural defence mechanisms no longer exist. Man's crops provide a specialised but profitable ecological niche for such soil fungi.

Economic status and control

Local information, the isolation of a Phytophthora sp. from pepper roots sent from Sarawak to Malaya (Thompson 1941), Muller's record of the disease from Indonesian Borneo, and a possible early Sarawak record (Hewett 1908) suggest that foot rot is no recent introduction.

Sarawak was a minor exporter of black pepper pre-war (1936-38, 2400 tons a year). Post-war scarcity brought about by the decline of the largest exporter - Indonesia - stimulated growers. Exports rose to a peak of 19,800 tons in 1956, but dropped to 8,400 tons in 1959. One of the biggest concentrations of planting was in the 1st division along the Kuching-Serian road. The main epiphytotic of 1953-55 occurred here. Conditions were favourable. Extensive contiguous holdings, one susceptible variety, and a husbandry and climate favouring the spread of a water-borne pathogen. The pepper close to the road in this area was largely wiped out. Crop loss can only be guessed at. Over 1953-56, direct losses might have amounted to 7000 tons, valued then at £1.7 million (pepper then contributing 23% of total exports).

The first, basic and most important step in control must be gradual rationalization of a husbandry still entirely empirical (Garrett 1955). Some measures suggest themselves. These are fencing, disinfection on entering holdings, abandonment of clean weeding, bottom pruning of lateral branches, and careful choice of planting sites. In theory, these are fairly simple; in practice they are a council of perfection divorced at present from reality. Agronomic research has only just begun. The Department, itself small, has to deal with a highly conservative, superstituous, and uneducated grower. His one method of dealing with foot rot is to bare the underground stem of earth; by itself this is ineffective. His calm, philosophic acceptance of loss is remarkable, but not surprising. His remarks suggest that foot rot is a real limiting factor to more extensive planting.

An experiment relying on natural infection and using dry cuprous oxide (Perenox) applied to the mound is still unfinished. To a limited extent, it has reduced spread. The word cultivar applied to Piper nigrum has little botanical precision about it. There seem to be two types of local pepper. After personal visits to Indonesia and India, the probable place of origin, 7 more types were introduced. One of these Muller had reported as partially field resistant. Preliminary tests with zoospore suspensions in the laboratory on roots and leaves indicated varying resistance in the 4 Indian and 2 of the Indonesian clones. The third Indonesian clone was as susceptible as the local types. The introduced peppers have recently (December 1959) been planted in a general field trial. Resistant root-stocks are an obvious possibility but grafting techniques need to be worked out.

It is hoped to publish a full account of this work as one of the Institute's series of Phytopathological Papers.

Acknowledgement is made to the Sarawak government and its Department of Agriculture.

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Ceratostomella WILT IN CACAO

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A wilt disease new to Trinidad cacao and caused by the fungus Ceratostomella [Ceratocystis] fimbriata broke out almost simultaneously in several isolated cacao areas in that island in March, 1958. The experimental cacao estate of the Regional Research Centre carried, at the time of the outbreak, a population of 90,000 trees. Of these trees 2,200 or 2.4% of the population have died from this disease between March, 1958, and March, 1960.

When one considers (1) that the loss of crop from each dead tree persists for at least several years; (2) the high cost of partial rehabilitation which is often accompanied by little prospect of success in establishing young cacao plants under already mature ones; (3) that the mortality rate on the above-mentioned estate jumped from 0.7% at the end of the first year to 2.4% at the end of the second year of the epidemic; then the potential menace to the economy of Trinidad cocoa becomes clear.

In the relatively short time since this disease appeared in Trinidad I have made studies of the biology of the pathogen and of its modes of dissemination with a view to prescribing rational control measures. Epidemiological studies have led to the conclusion that wind is in some way involved in the transmission of this disease. While field surveys were proceeding other studies were indicating that several difficulties might be encountered in controlling this disease. For example the pathogen produces as many as four different spore forms: (1) thin-walled endoconidia, (2) thick-walled endoconidia, (3) chlamydospores, and (4) ascospores.

To deal first with the spores that appear to be most important - the chlamydospores. These are disseminated by at least six different species of minute wood-boring beetles of the genus Xyleborus. These insects, of the order of 1.5 to 2.0 mm. long, are invariably found to infest C. fimbriata infected cacao trees. They ingest infected wood containing chlamydospores. These spores then pass through the alimentary canal of the insects, are voided in the faeces, and still retain their viability. In addition to this the chlamydospores are also liberated to the wind from the diseased host in the finely divided dust extruded by the insects during their tunelling.

It is also highly probable that Xyleborus spp. transmit the disease by transporting the mucilaginous ascospore masses which exude from the perithecial ostiole and adhere to the insects' bodies.

Lastly, the endoconidia do become air-borne. They are produced in profusion on cut or broken bark or wood and also on the surface of dust coils extruded by the insects.

Despite its destructiveness, inoculation experiments show that the pathogen is a weak parasite. All these spore forms need wounds for successful invasion of cacao. As it is, however, almost impossible to cultivate cacao without wounds there appears to be little hope of disease escape.

Perhaps the most profitable method of combating this complex lies in the control of the insects which, in addition to being active vectors, also produce the finely divided dust which is the vehicle for wind dispersal of chlamydospores of the pathogen. Control of the insects will, however, necessitate very precise timing of insecticidal applications based on the detailed study of the life-cycle of

the insects, which appear to spend virtually all their life within the wood and emerge only as young adults in search of new boring sites on other trees. Failing such timely applications, suitable systemic insecticides may have to be sought. In the meantime, however, study of this disease continues and other methods such as complete eradication of diseased trees and general phytosanitary practices are being employed in an attempt to slow down the epidemic.

Discussion following papers by J. W. Blencowe & A. L. Wharton

N. F. ROBERTSON (U.K.) asked if there was any evidence that a reduction in the insect population reduces black pod infection. Might insects carry the diseases and could this explain the deficiency?

A. L. WHARTON replied that the regressive figure in Ghana agrees closely with that in Nigeria from single tree data. However, because of shortage of plots he had not been able to work on the insect aspect.

C. A. THOROLD (U.K.) said that although there were certain differences there seemed to be a similarity between the behaviour of the disease with both the Ghanaian and Nigerian strains of Phytophthora. His own data had been obtained from records of the total number of pods on a large number of individual trees, and the method was described in a paper given at the 1953 cocoa conference. By that method, it had seemed that in a number of cases with very low groupings there were fewer black pods to be observed than expected, whereas conversely where there were large numbers of pods per tree the numbers of black pods exceeded expectations. Hence, we agree that the general relationship between numbers of black pods and pods per tree is similar in Ghana and Nigeria.

The opposite approach, which is more theoretical and harder to establish, is that there may be a causal relationship between numbers of black pods and total pods. There is some indication that loss through black pod may stimulate production of pods, but this may never be established because of variability of pod production in different trees. Nevertheless, it may lead to interesting considerations in connection with disease control. If pod removal will not greatly limit production then early removal of black pods may be beneficial. Early incidence often seems to be on low pods, and in certain places low pods are actually removed to control the disease. If epidemics may start from the lower pods on the trees, it may well be worth while removing such pods as a preventive measure.

Discussion following paper by P. D. Turner

MISS G. M. WATERHOUSE (U.K.) commented that the terms 'cacao' and 'rubber' strains are used in inverted commas, as these can be obtained from a number of hosts as is shown in the literature on the subject.

Discussion following paper by A. A. Brunt and A. L. Wharton

W. J. DOWSON (U.K.) said that working in conjunction with Dr. Hayward in the tropical glasshouse at Cambridge, gall-like structures were produced on half beans and young seedlings by inoculation with seedling gall extracts from Ghana and British Honduras. These structures developed after 3 weeks and were similar to those described in Wharton's paper. This work is continuing and recently the young plants have been subjected to tropical daylight lengths (18 hours); the plants do not grow so fast with 12 hour daylight periods and this might affect the pathogen. Brunt now believed that a fungus, or a fungus and bacterium together might be involved.

A. C. HAYWARD (U.K.) added that numerous isolations of bacteria had been made at the C.M.I. from cushion gall specimens from Ghana, British Honduras, Costa Rica, Trinidad, and Venezuela. An organism resembling Agrobacterium tumefaciens was present in each case, but inoculation of half beans with this organism at Cambridge proved negative. Similar experiments carried out in Ghana also proved negative. There is thus no evidence from the half bean inoculation method that this bacterium is the cause of seedling axillary gall formation.

AUTHORS

Ainsworth, G.C., 17
Blake, C.D., 53
Blencowe, J.W., 139
Brunt, A.A., 148
Cammack, R.H., 134
Dade, H.A., 31
de Silva, R.L., 83, 112
de Tempe, J., 67
Ellis, M.B., 30
Fox, R.A., 41, 97
Fraser, L.R., 120
Gibson, I.A.S., 39
Goodchild, N.A., 39
Hainsworth, E., 91
Hayward, A.C., 35
Holliday P., 156
Hutton, K.E., 89
Iton, E.F., 161
Large, E.C., 75
Lelliott, R.A., 38
Logan, C., 84
Lupton, F.H.G., 123
Macer, R.C.F., 123
Magee, C.J., 117
Marks, G.C., 94
Mulder, D., 83, 112
Murray, J.S., 51
Neergaard, P. 60
Noble, M., 57
Ogilvie, L., 83
Peiris, J.W.L., 94, 115
Perry, D.A., 48
Priest, D., 106
Riggenbach, A., 40
Skolko, A.J., 26
Spencer, D.M., 100
Thorpe, I.G., 83
Turner, P.D., 147
van Beverwijk, A.L., 33
van der Plank, J.E., 79
Waterhouse, G.M., 23
Watson, I.A., 125
Wharton, A.L., 139, 148
Wood, R.K.S., 106

INDEX

Calling the Conference 1
Delegates 1
Visitors 2
Place of Meetings 2
Official Reception 2
Programme 3
Excursions 4
Opening of the Conference 4
Work and Organization of the Commonwealth Mycological Institute 5
Appointment of Committees 6
Proceedings of Conference 6
Report of Technical Committee 6
Resolutions 8
Votes of thanks 8
Director's Review of the Work of the Institute 11
Information Service for Plant Pathology
- The Review of Applied Mycology, G.C. Ainsworth 17
- The Review of Applied Mycology and other C.M.I. Information Services, G.M. Waterhouse 23
- Discussion 24

Taxonomy in relation to Plant Pathology
- The Status of taxonomic mycology in present day plant pathology, A.J. Skolko 26
- Herb.I.M.I. and the identification service, M.B. Ellis 30
- The C.M.I. Culture Collection, H.A. Dade 31
- Are "type cultures" type material? A.L. van Beverwijk 33
- The identification of plant pathogenic bacteria, A.C. Hayward 35
- The functions of a culture collection of plant pathogenic bacteria and bacteriophages, R.A. Lelliott 38
- Discussion 38

Root Diseases
- Armillaria mellea in Kenya tea plantations, I.A.S. Gibson and N.A. Goodchild 39
- Recent progress in the control of white root diseases of Hevea rubber A. Riggenbach 40
- The white root disease of Hevea brasiliensis: recent developments in control techniques, R.A. Fox 41

The interaction of Fusarium oxysporum f. vasinfectum and Meloidogyne spp. on cotton, D. A. Perry 48
Control of Fomes annosus in Britain today, J. S. Murray 51
Radopholus root rot of bananas, C. D. Blake 53
Discussion 54

Seed pathology
Seed pathology - retrospect and prospect, M. Noble 57
Uniformity in seed health testing, P. Neergaard 60
The present state of health testing of seeds, J. de Tempe 67
Discussion 74

Forecasting and Assessment
Forecasting and assessment, progress curves, E. C. Large 75
Errors due to spore dispersion in field experiments with epidemic diseases, J. E. van der Plank 79
Blister blight control of tea based on sunshine records, D. Mulder and R. L. de Silva 83
Black rust of wheat: co-operative investigations in western Europe and North Africa, L. Ogilvie and I. G. Thorpe 83
An estimate of the effect of seed treatments in reducing cotton crop loss caused by Xanthomonas malvacearum in Uganda, C. Logan 84
Availability of Venturia inaequalis and Venturia pirina ascospores in New South Wales, K. E. Hutton 89
An estimate of the avoidable losses from plant diseases in Kenya, E. Hainsworth 91
Discussion 93

Fungicides
The comparison of the efficacy of antimycin, blastmycin, and blasticydin 'S' with mercurial fungidies for controlling blast of rice, G. C. Marks and J. W. L. Peiris 94
White root disease of Hevea brasiliensis: the role of fungicides in control techniques, R. A. Fox 97
Volatile fungicides and their possible use in crop protection, D. M. Spencer 100
Adaptation of fungi to fungicides, D. Priest and R. K. S. Wood 106
Discussion 109

Virus Diseases and Cereal Rusts
The relation between air temperature and the occurrence of symptoms of phloeum necrosis virus diesease, D. Mulder and R. L. de Silva .. 112
Tristeza disease in Ceylon affecting orange seedlings, J. W. L. Peiris . 115
The latent infection problem in the control of abaca (Manila hemp) mosaic, C. J. Magee 117
Leafroll of grapevines in New South Wales, L. R. Fraser 120
The genetics of yellow rust resistance in wheat, F. H. G. Lutpon and R. C. F. Macer 123
Basic aspects of breeding rust resistant wheats, I. A. Watson 125
Puccinia polysora: a review of some factors affecting the epiphytotic in in West Africa, R. H. Cammack 134
Discussion 138

Diseases of Cacao and Black Pepper
Black-pod disease in Ghana: incidence of the disease in relation to levels of productivity, J. W. Blencowe and A. L. Wharton 139
Strains of Phytophthora palmivora (Butl.) Butl. occurring in West Africa, P. D. Turner 147
A gall disease of cocoa (Theobroma cacao L.) in Ghana, A. A. Brunt and A. L. Wharton 148
A root disease of black papper in Sarawak, P. Holliday 156
Ceratostomella wilt in cacao, E. F. Iton 161
Discussion 162

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